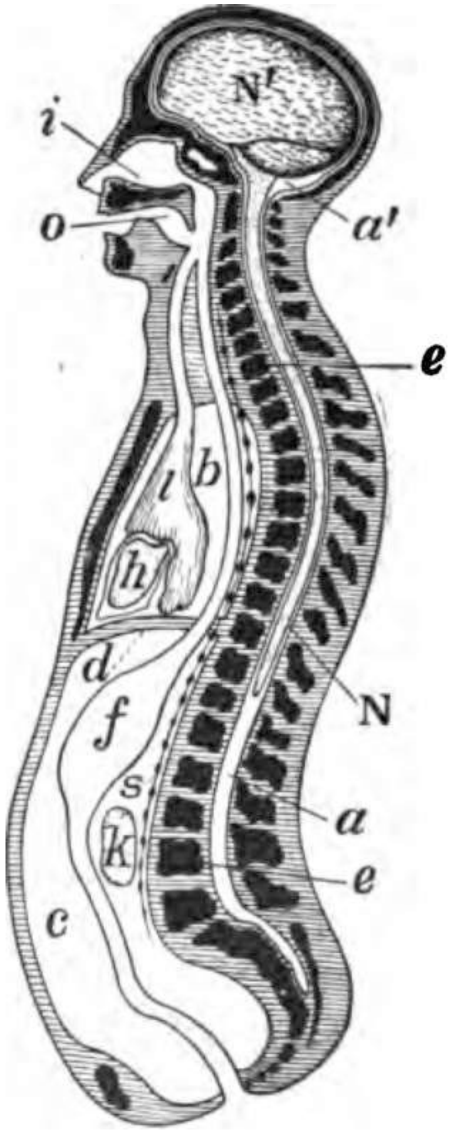
Human Physiology PCB 4701

Neurons
Fox Chapter 7 pt 1



Structure of Vertebrates

Two major compartments of the body

Peripheral Compartment

Everything outside of the brain and spinal cord (heart, lungs, gastrointestinal tract, liver, kidneys, skeletal muscle, skin etc.)

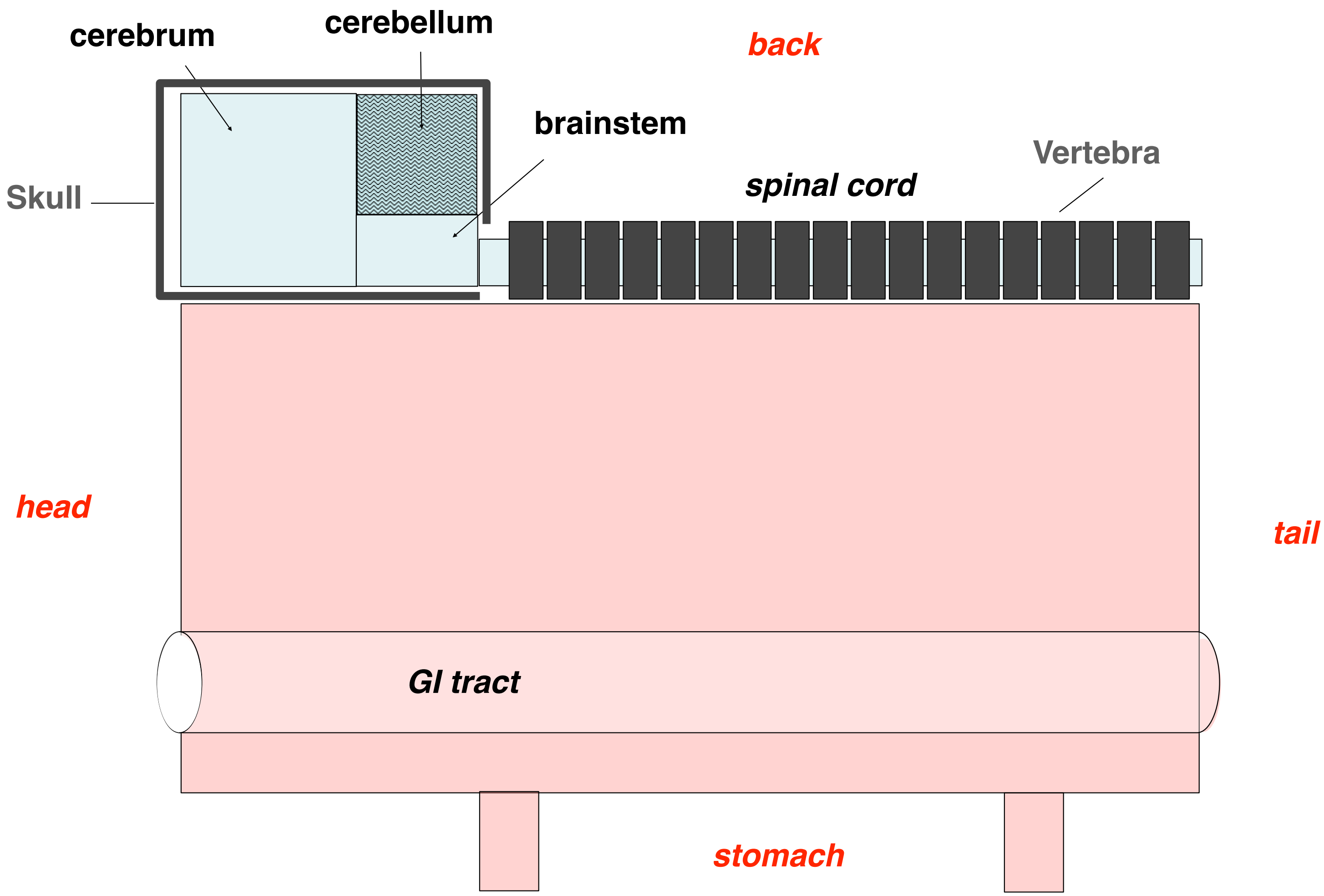
Central Nervous System (CNS)

- Brain at front of body
- Spinal cord running down the back
- Protected by skull and vertebra
- Sensory receptors clustered in head (vision, hearing, taste, smell)

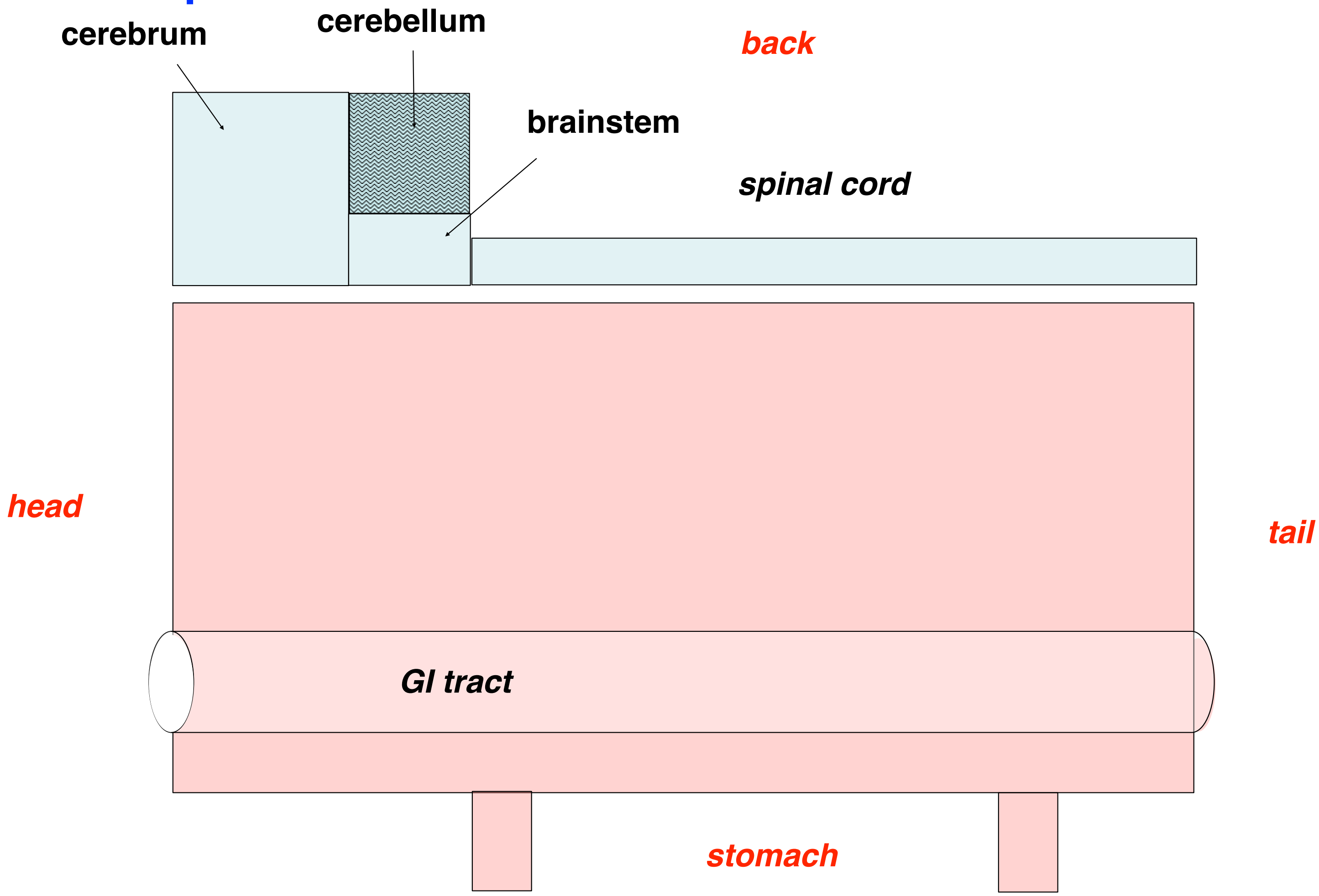
http://bookdome.com/health/anatomy/Human-Body/Man-Is-A-Vertebrate-Animal.html

Vertebrate Central Nervous System:

brain & spinal cord

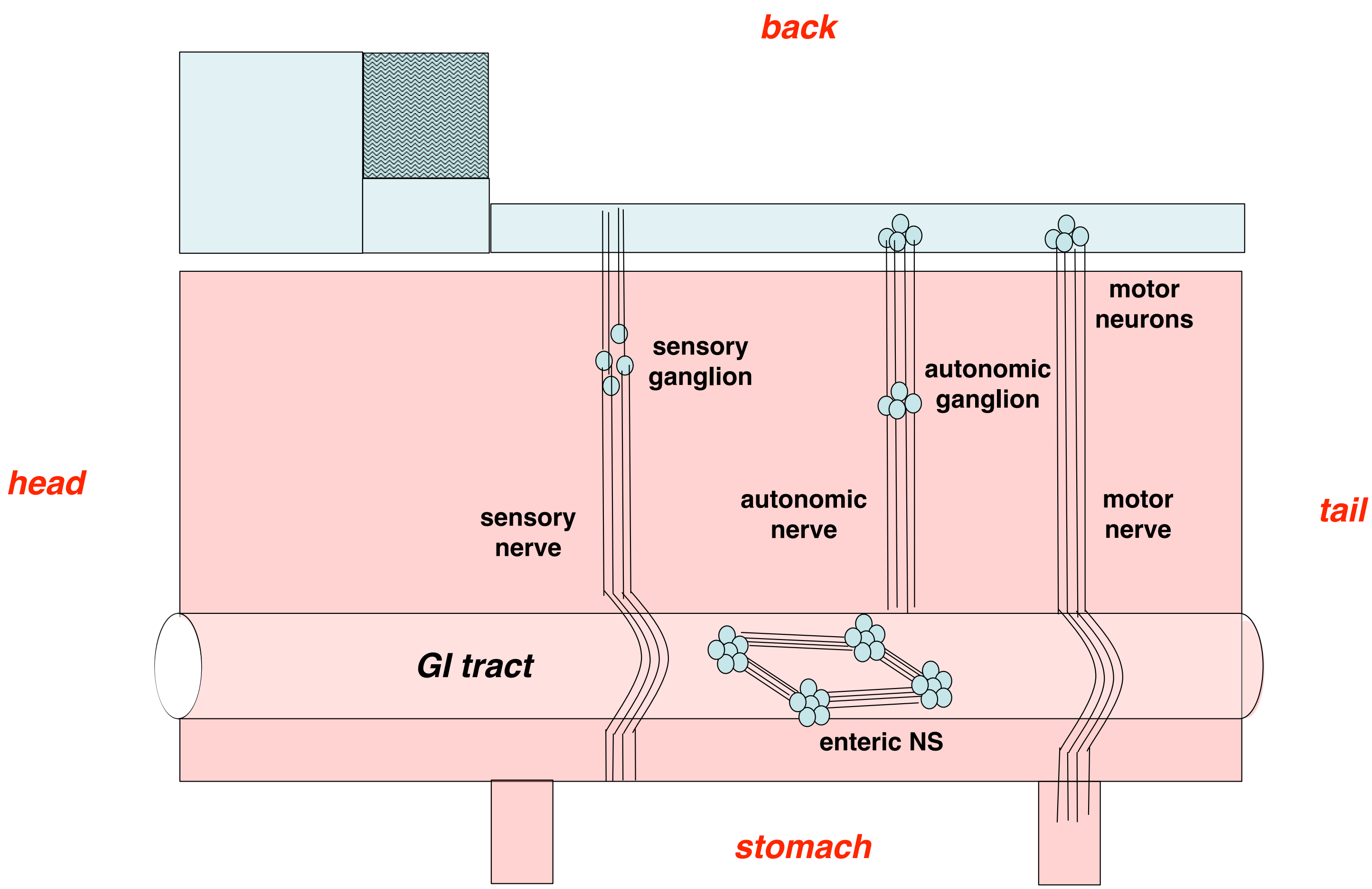


Vertebrate Central Nervous System: brain & spinal cord



Peripheral Nervous System:

Neurons and nerve fibers outside the brain and spinal cord



Functions of the Nervous System

Sensory Motor Integration
Detect changes in the environment or in the body via sensory receptors; coordinate responses across the body. Initiate responses via skeletal muscle (**somatic** nerves for voluntary movement) or via smooth muscle and glands (**autonomic** nervous system).

Neurons (nerve cells)
Point to point communication across the body to coordinate responses
Integrate electrical and chemical signals at **dendrites** & cell body; depending on inputs, neuron sends electrical and chemical signal down **axon** to **synapse** on target cell.

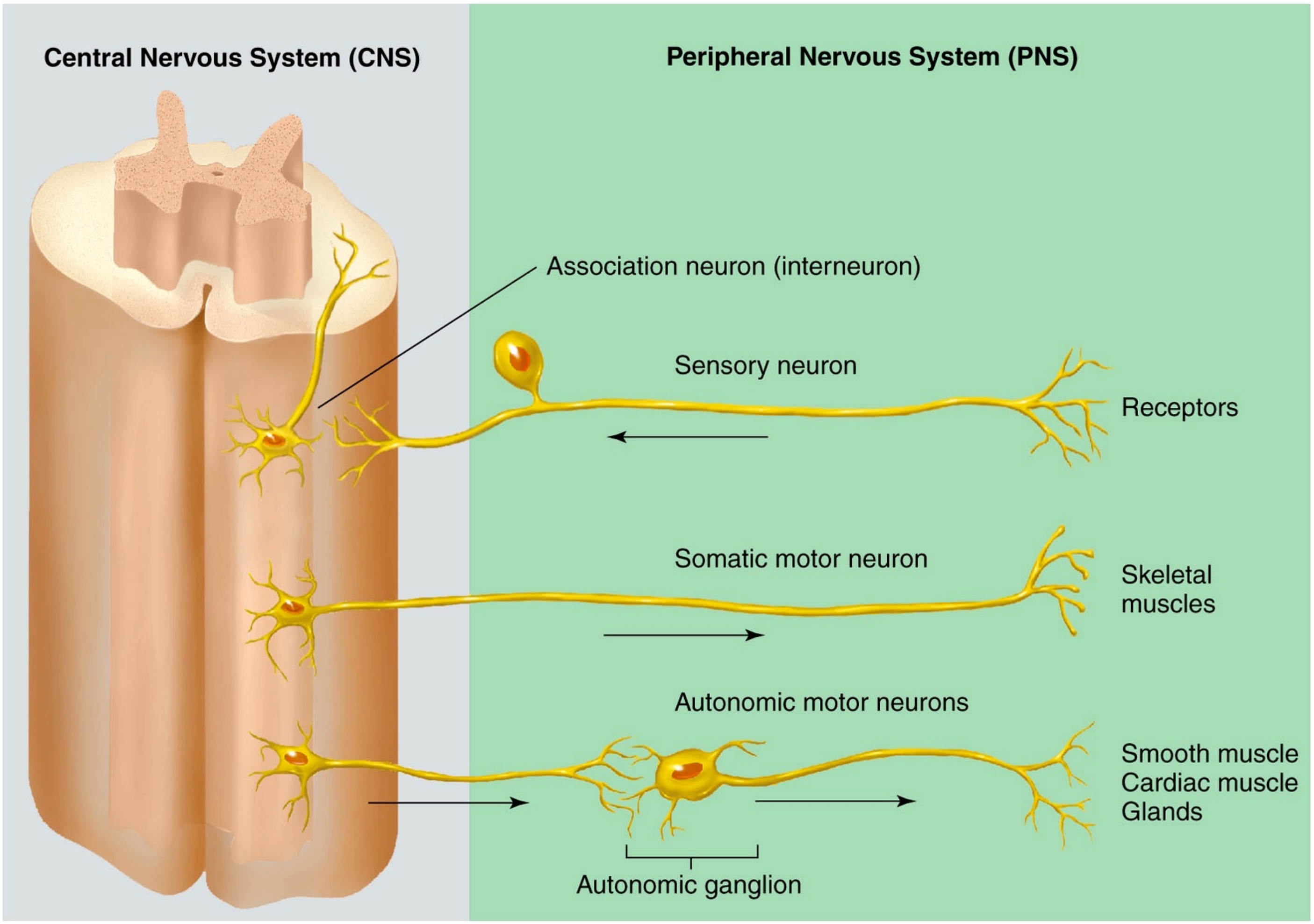
Sensory neurons (afferents)
carry sensory information into the CNS

Motor neurons (efferents)
carry impulses out of CNS to make muscles move or effect target organs (e.g. glands)

Association neurons
Neurons within the CNS that process information

Nucleus: cluster of neuron cell bodies in brain (gray matter)
Tract: bundle of axons connecting regions of brain & spinal cord (white matter)

Ganglion: cluster of neuron cell bodies in the peripheral body
Nerve: bundle of axons surrounded by glial cells in periphery



Fox Figure 7.3

Anatomy of Neurons

Cell body
Nucleus, endoplasmic reticulum, Golgi apparatus, etc.

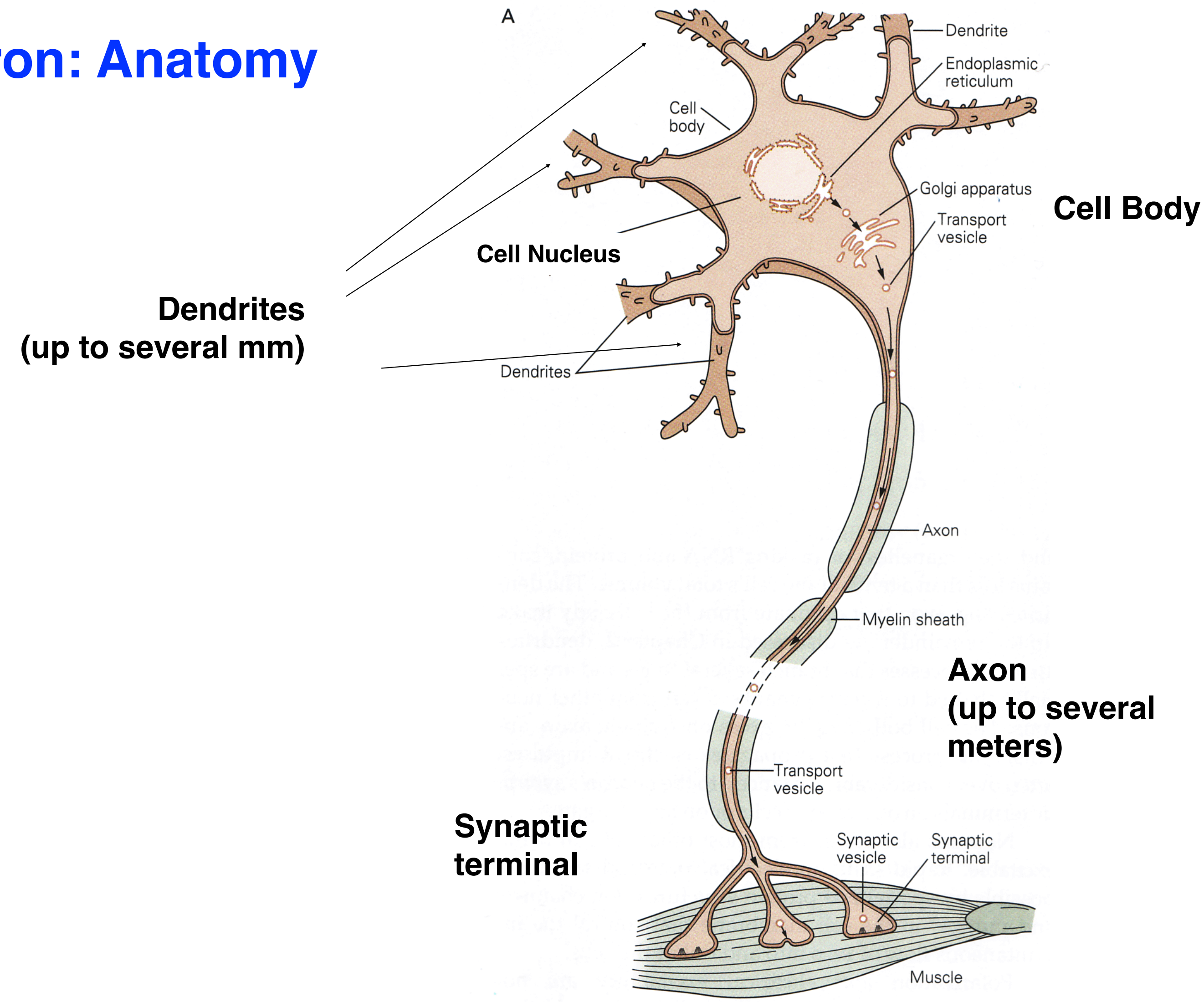
Dendrites (*branches*) - Inputs of the neuron.
Many sensory receptors or other neurons release chemical signals onto receptor molecules in the dendrites.

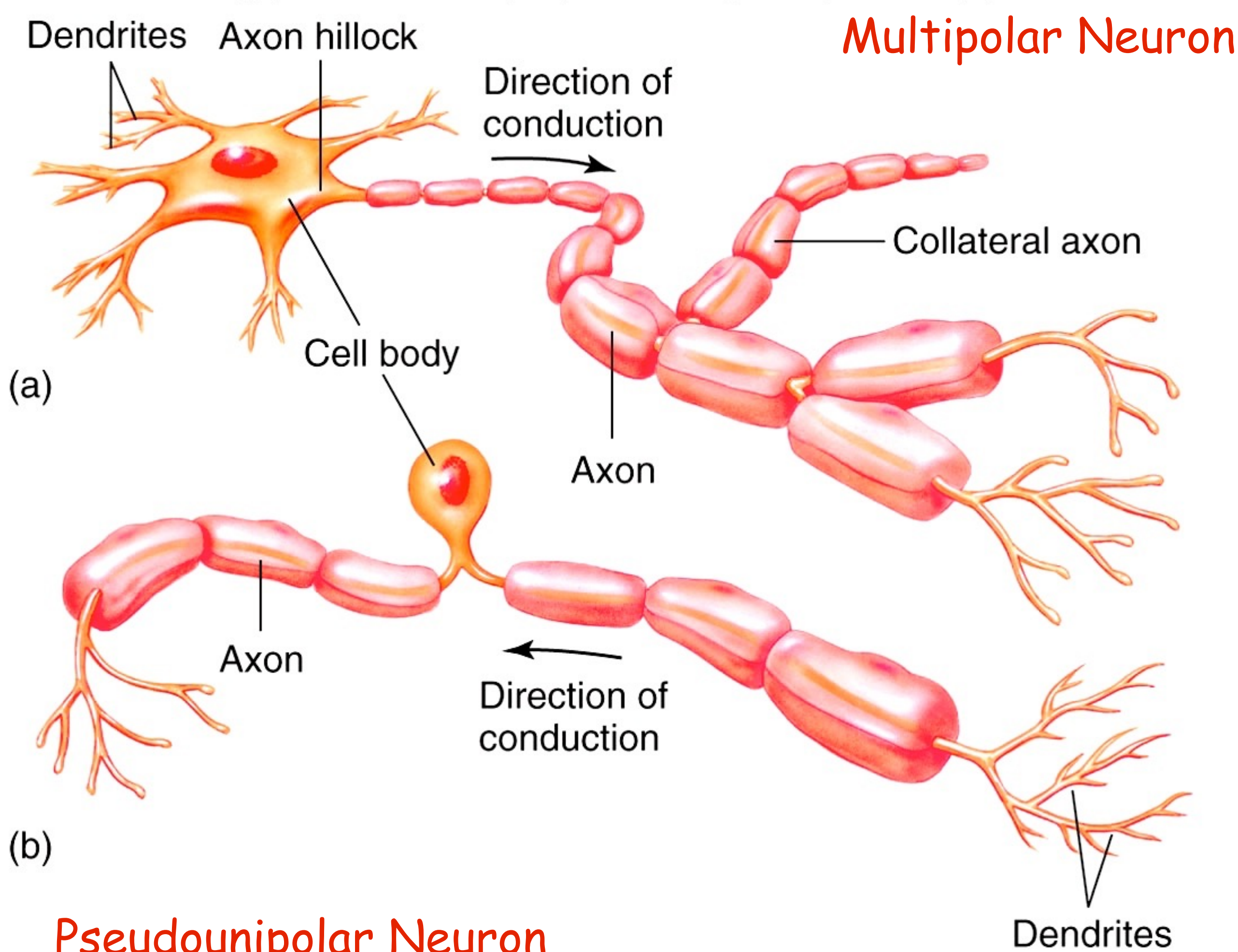
Axon - Output of the neuron:
Long fiber, extending up to meters to carry output signal (action potential) of neuron to target cells.

Synapses
connections between the axon of a neuron (presynaptic cell) with a target cell (postsynaptic cell).

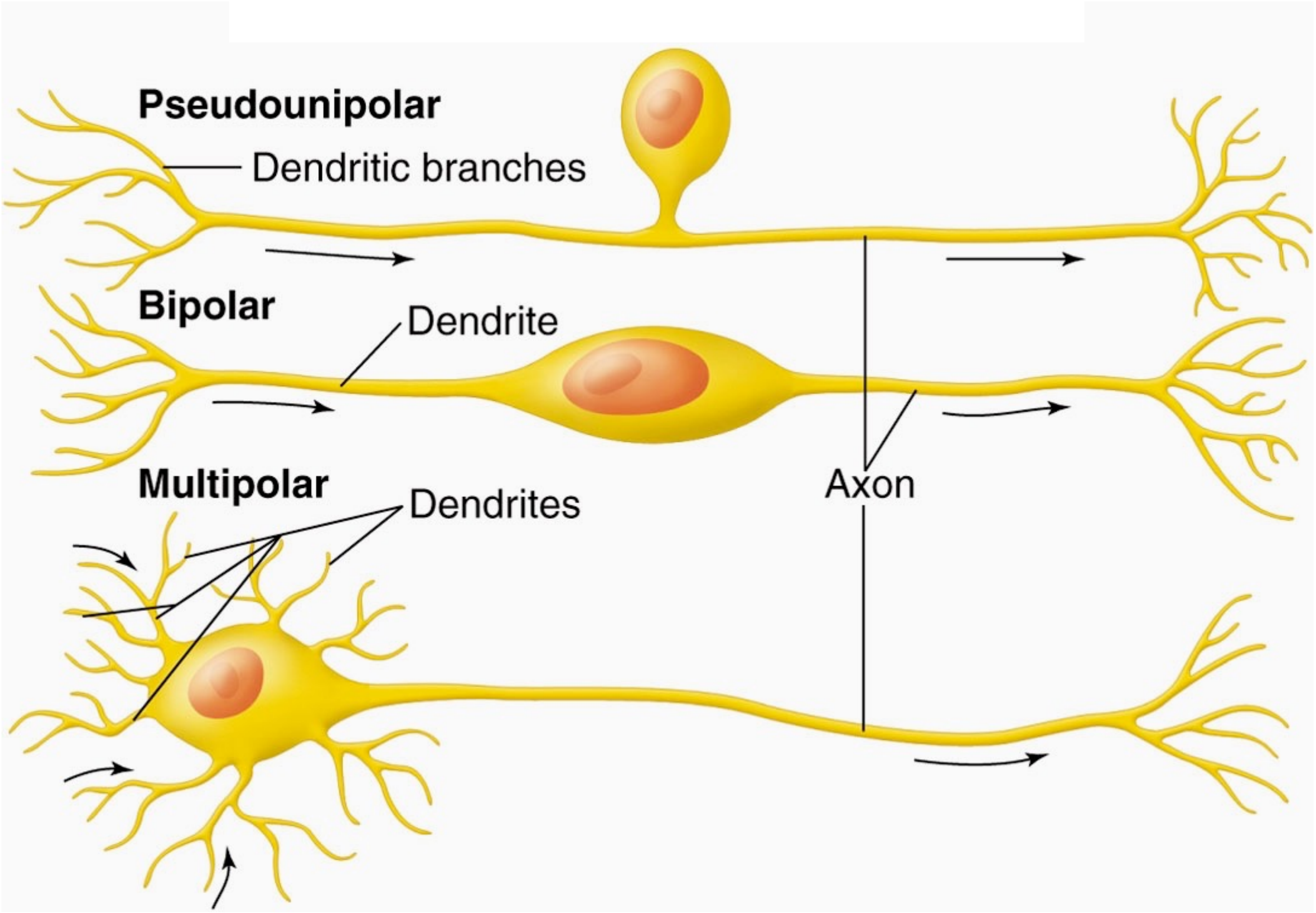
Postsynaptic target cell
could be another neuron, or it could be muscle or gland cells.

Neuron: Anatomy



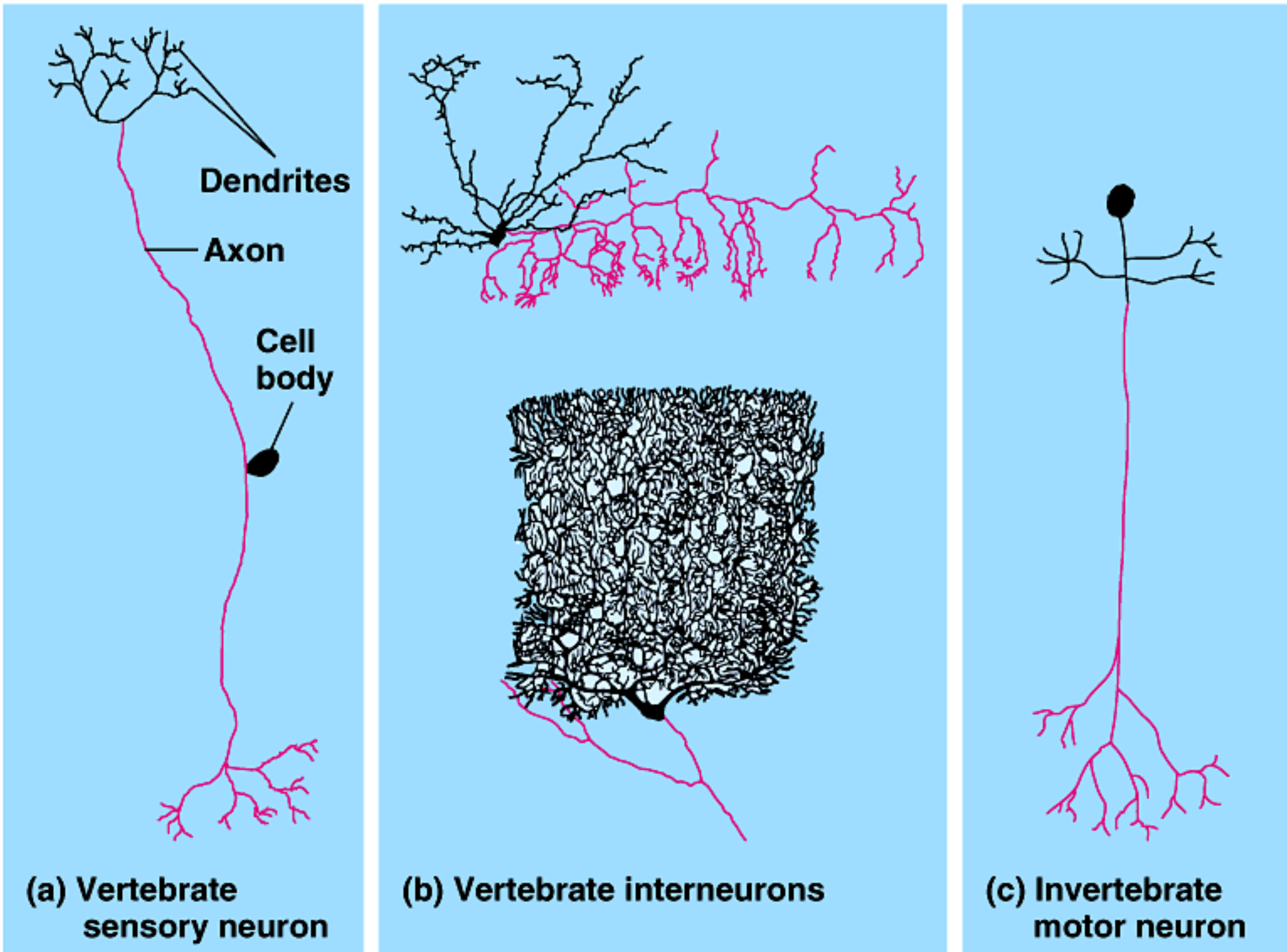


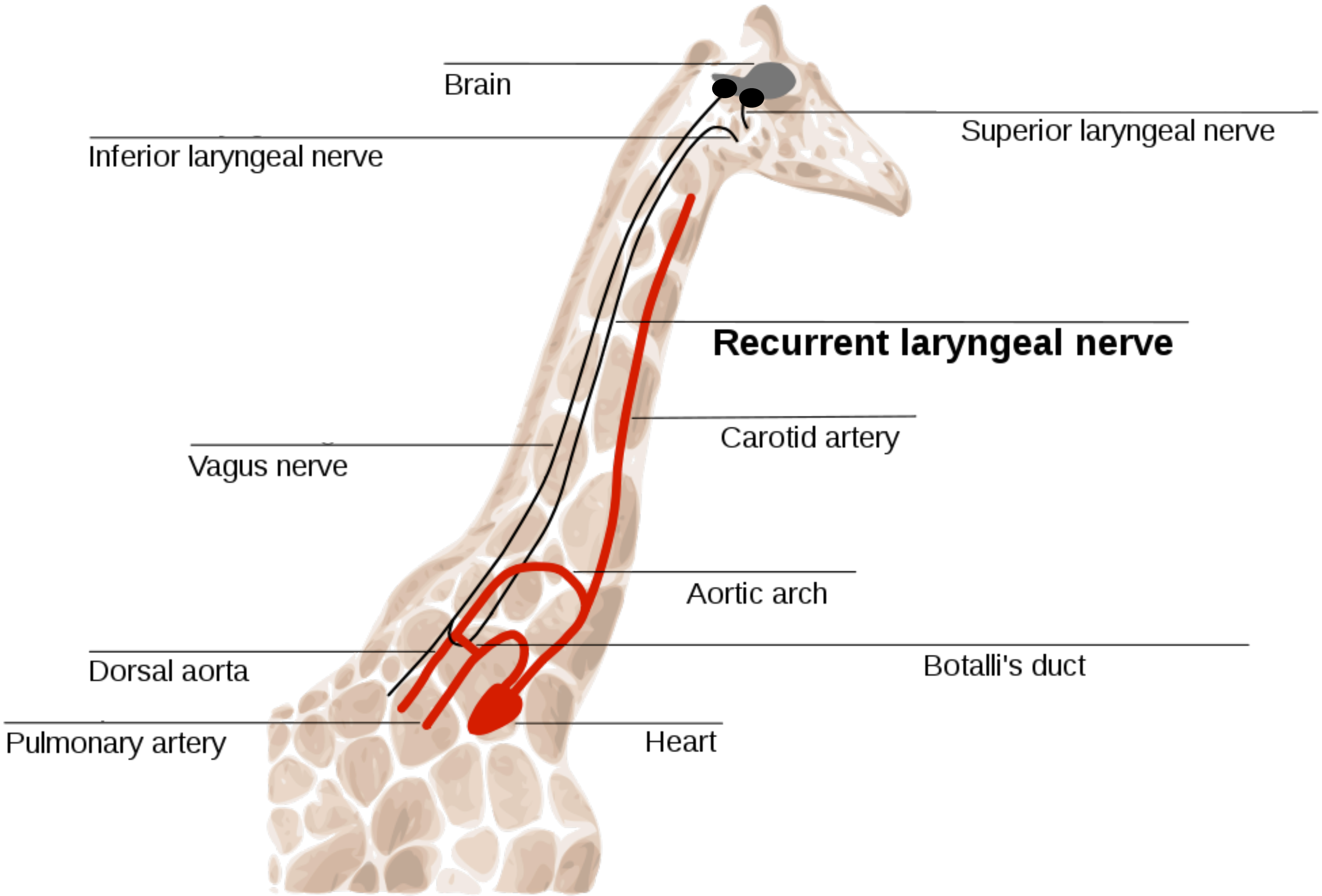
Fox Figure 7.1



Fox Figure 7.4

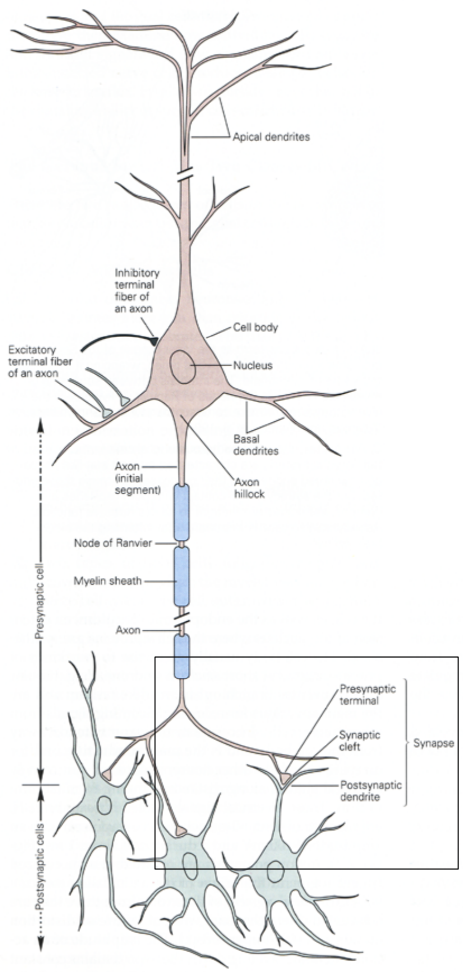
Campbell Figure 48.4 Structural diversity of neurons

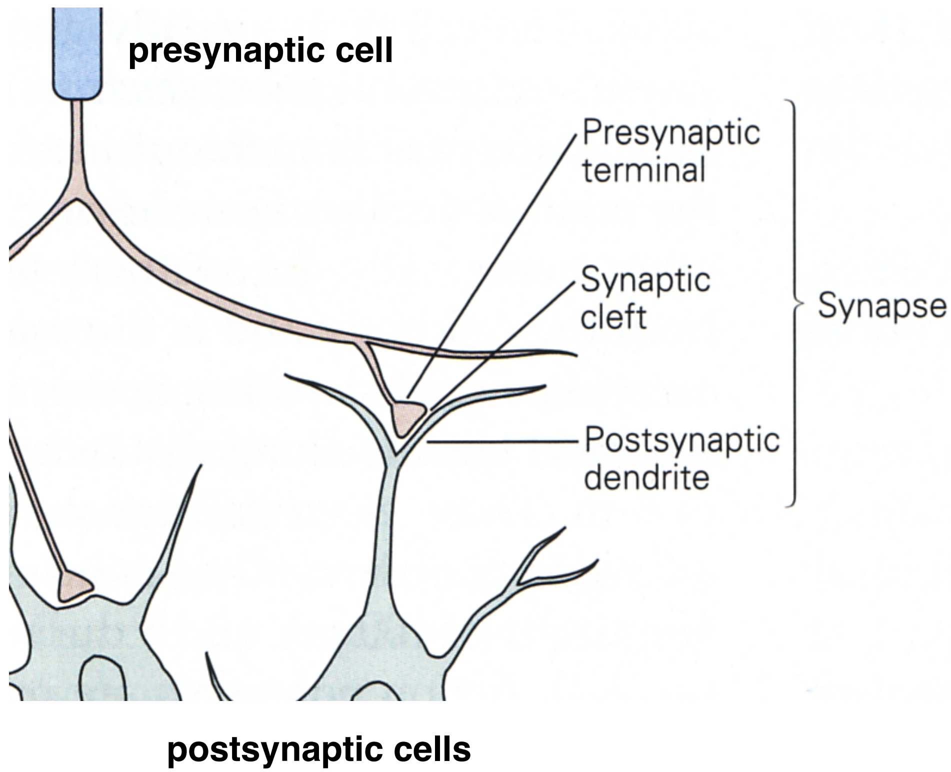




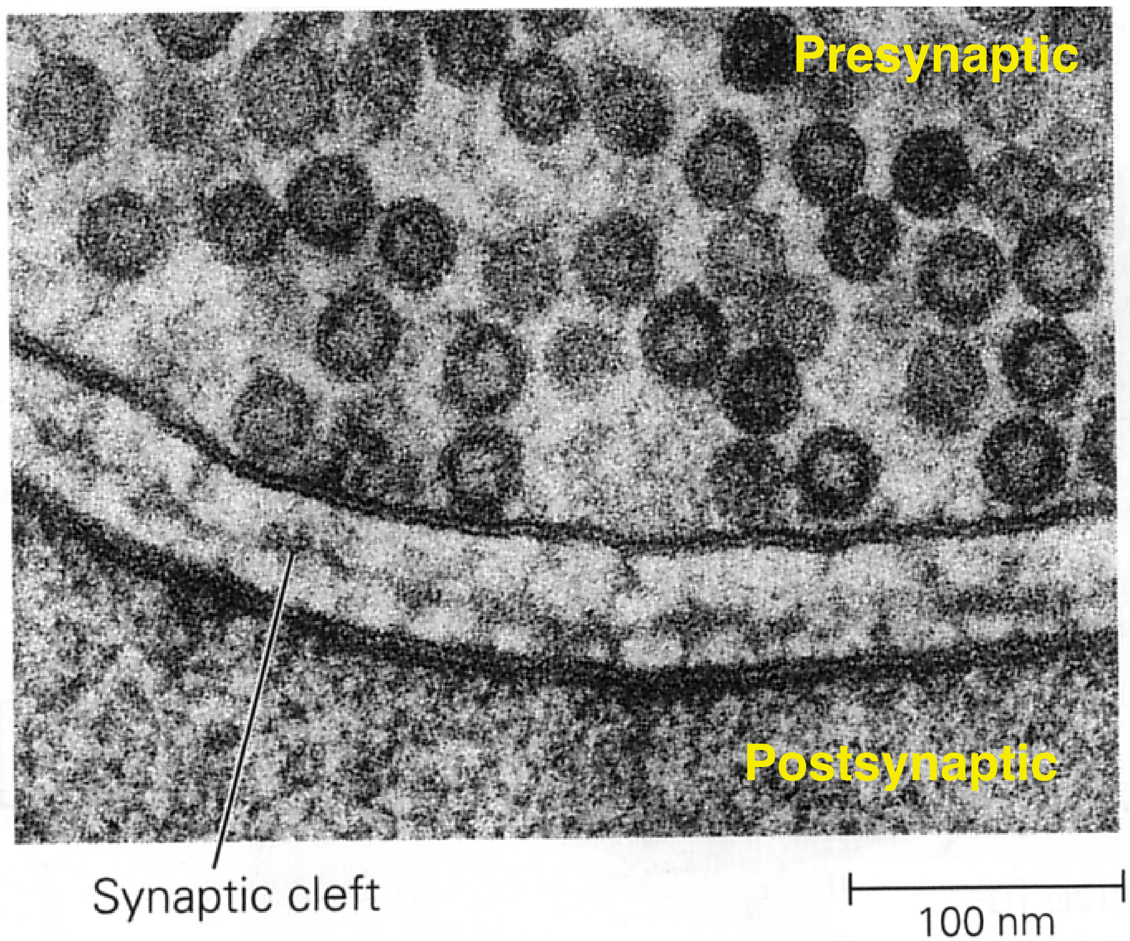
GiraffaRecurrEn.svg, *Wiki Commons, Vladimir V. Medeyko)*

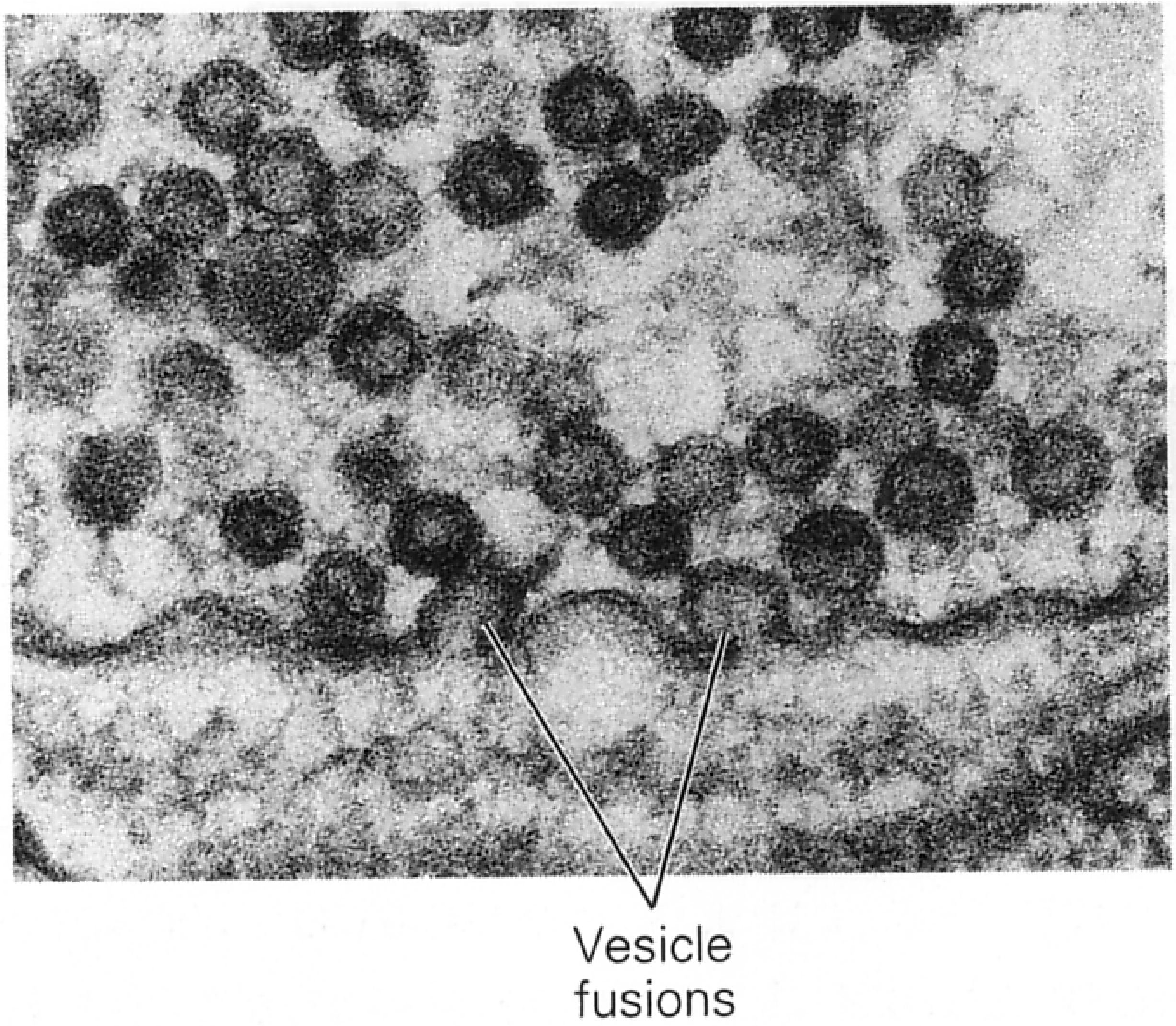
Neuron: Synapse

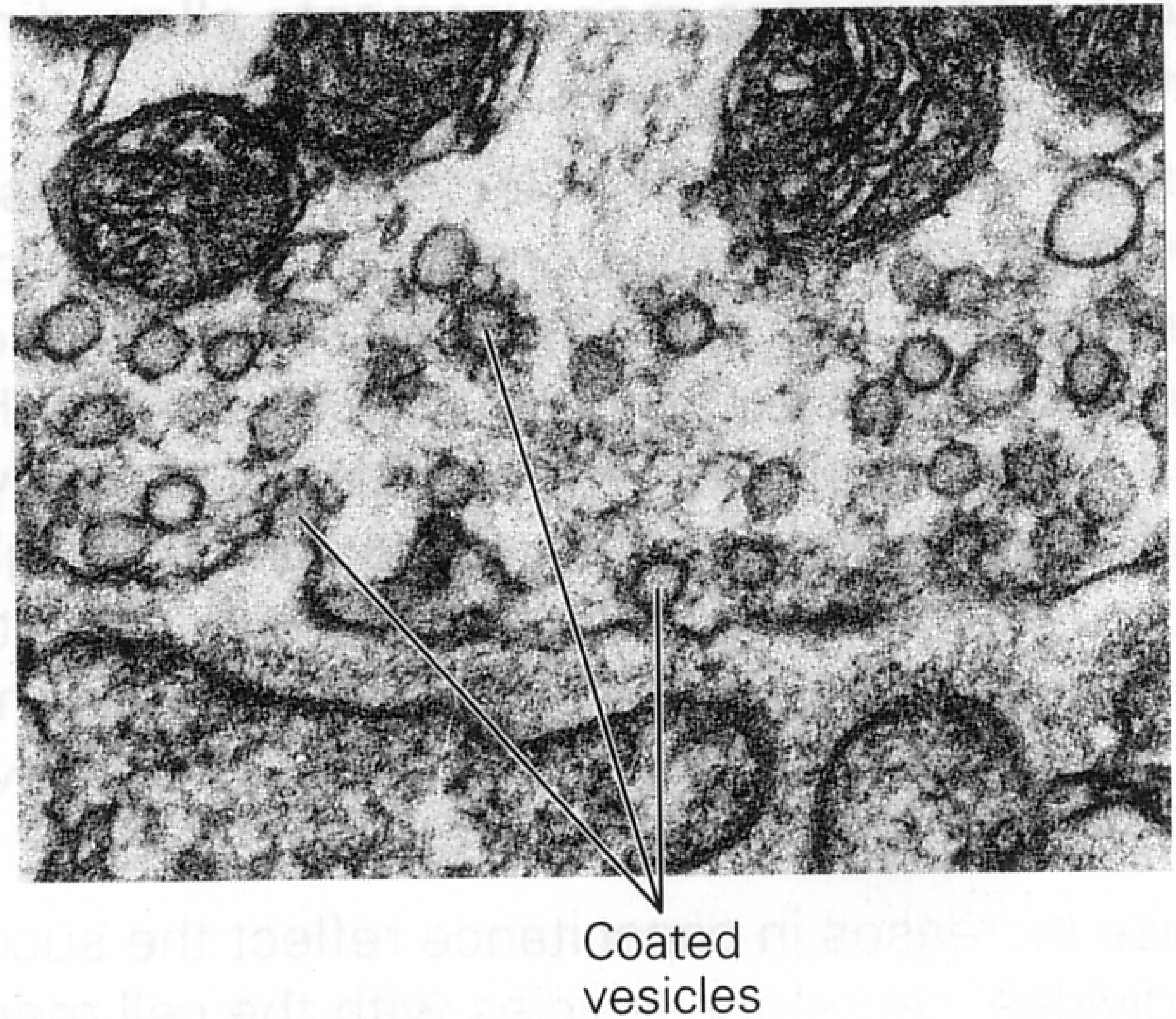




Presynaptic Membrane
(thin section with electron microscope)




Vesicle
fusions


Coated
vesicles

TOP HAT

NEURONS OUTPUT/INPUT

Branching of Dendrites and Axons increases connectivity:

CNS is very interconnected:

Total number of neurons in cerebral cortex = 10 billion

Total number of synapses in cerebral cortex = 60-200 trillion (yes, trillion)

(G.M. Sheperd 1998)

Achieved by large increase in surface area:

Surface area of 10 μm wide spherical cell = 300 μm^2

Surface area of a typical neuron = 250,000 μm^2

Surface area of all 100 billion neurons in brain = 25,000 m^2

(the size of four soccer fields -- M. Bear et al 2001)

2010: Simulation of 4.5% of Human Brain Cortex

100% possible in 2022?

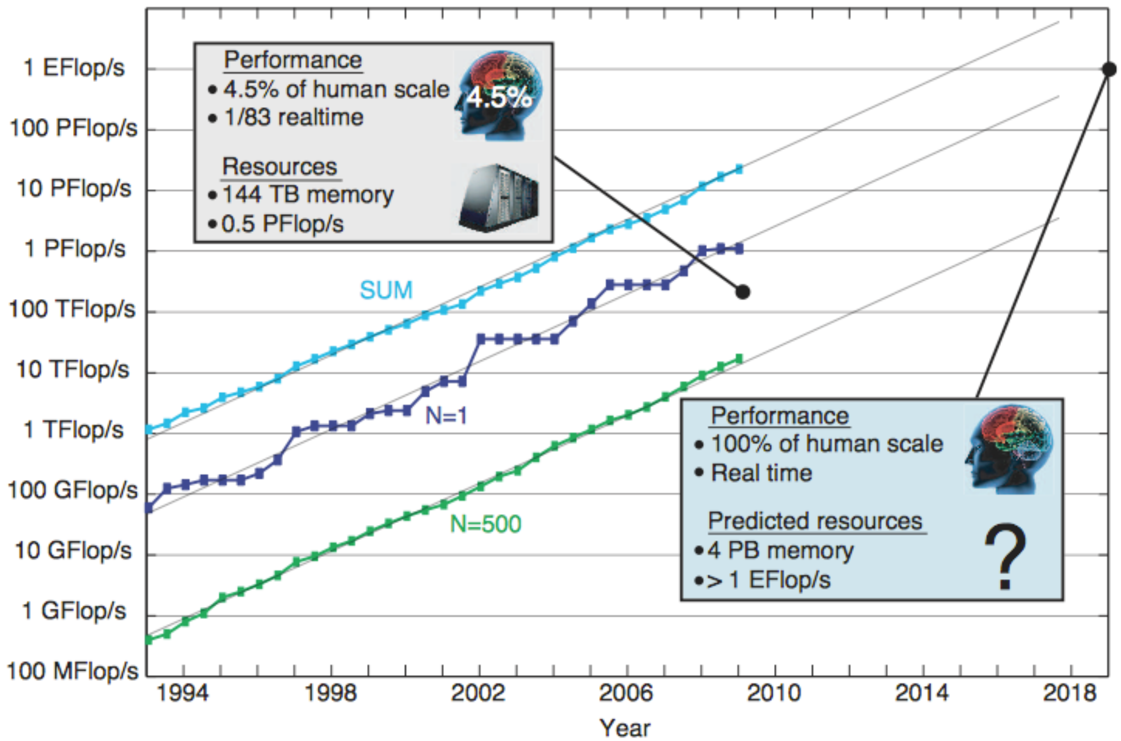


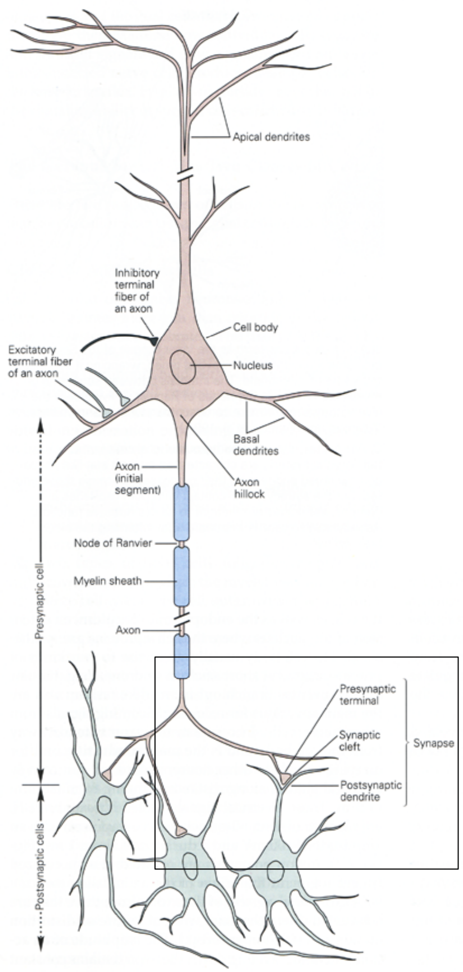
Figure 8: Growth of Top500 supercomputers [25] overlaid with our result and a projection for realtime human-scale cortical simulation.

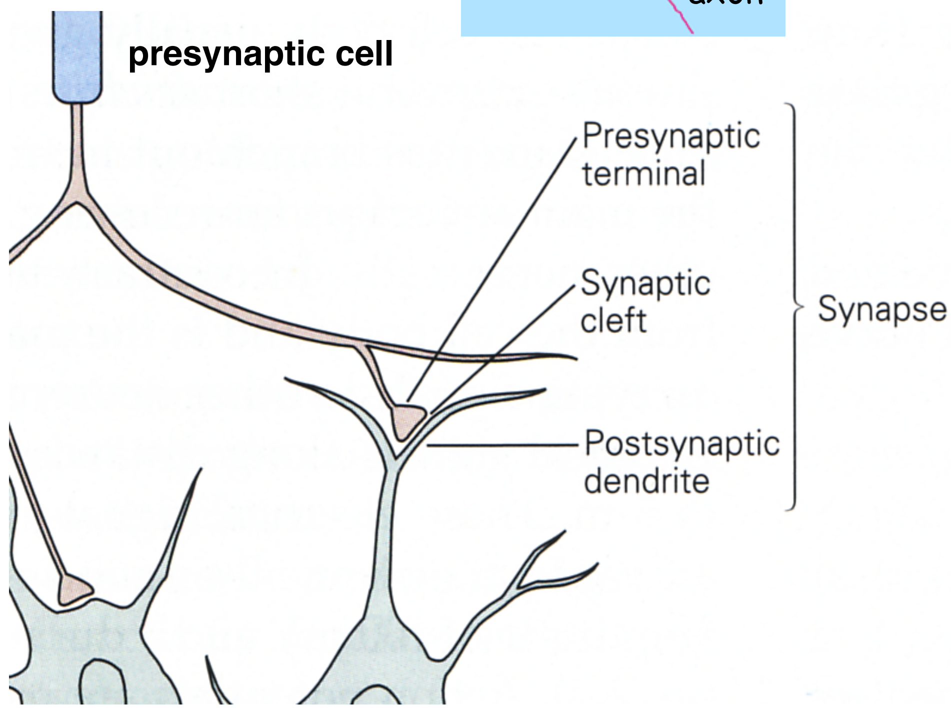
Frontier at Oak Ridge Natl Lab (2022)
1.1 Exaflops
9,400 CPUs and more than 37,000 GPUs
700 petabytes storage

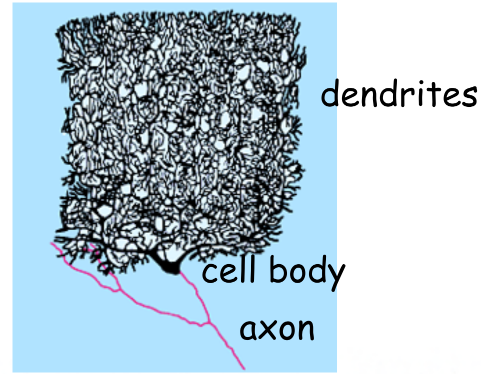
http://www.modha.org/C2S2/2009/11182009/content/SC09_TheCatIsOutofTheBag.pdf

https://www.olcf.ornl.gov/frontier/

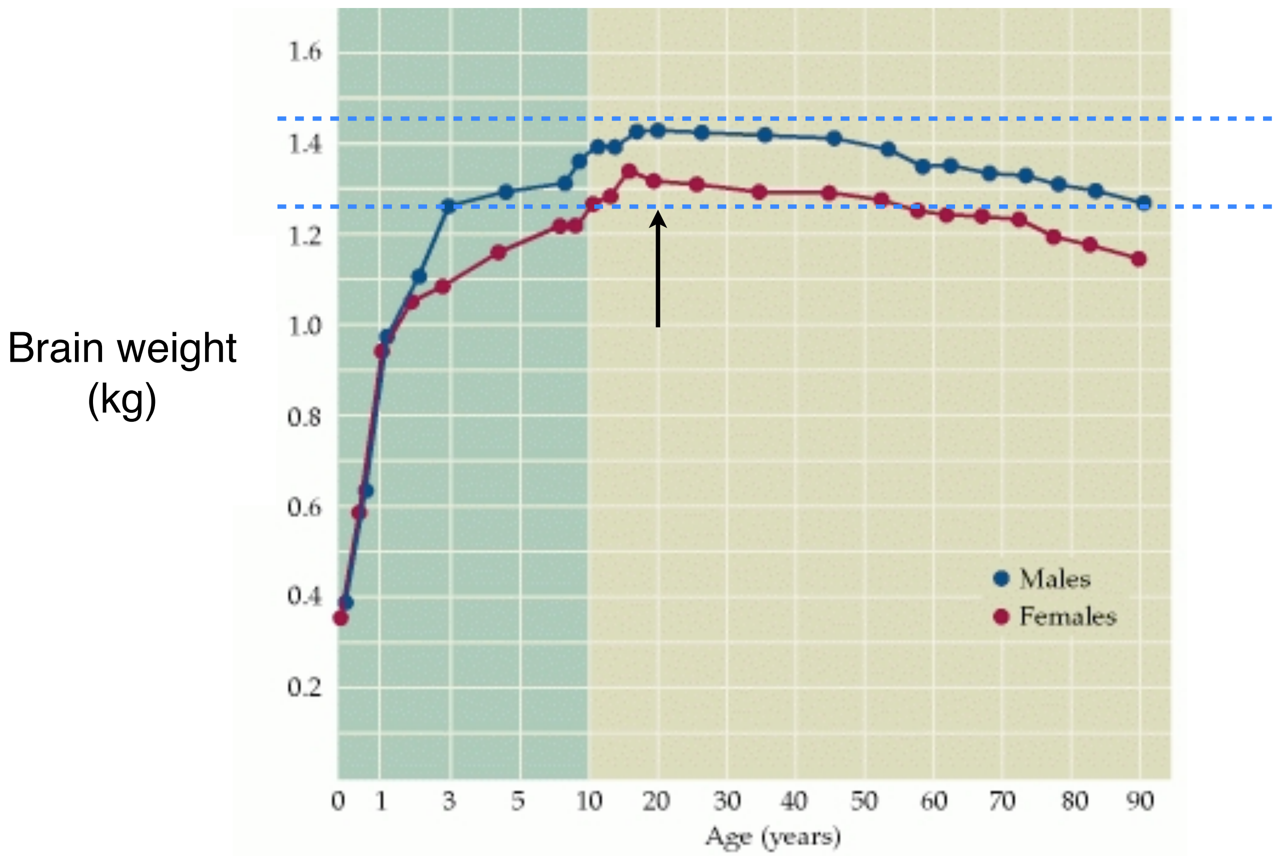
Neuron: Synapse







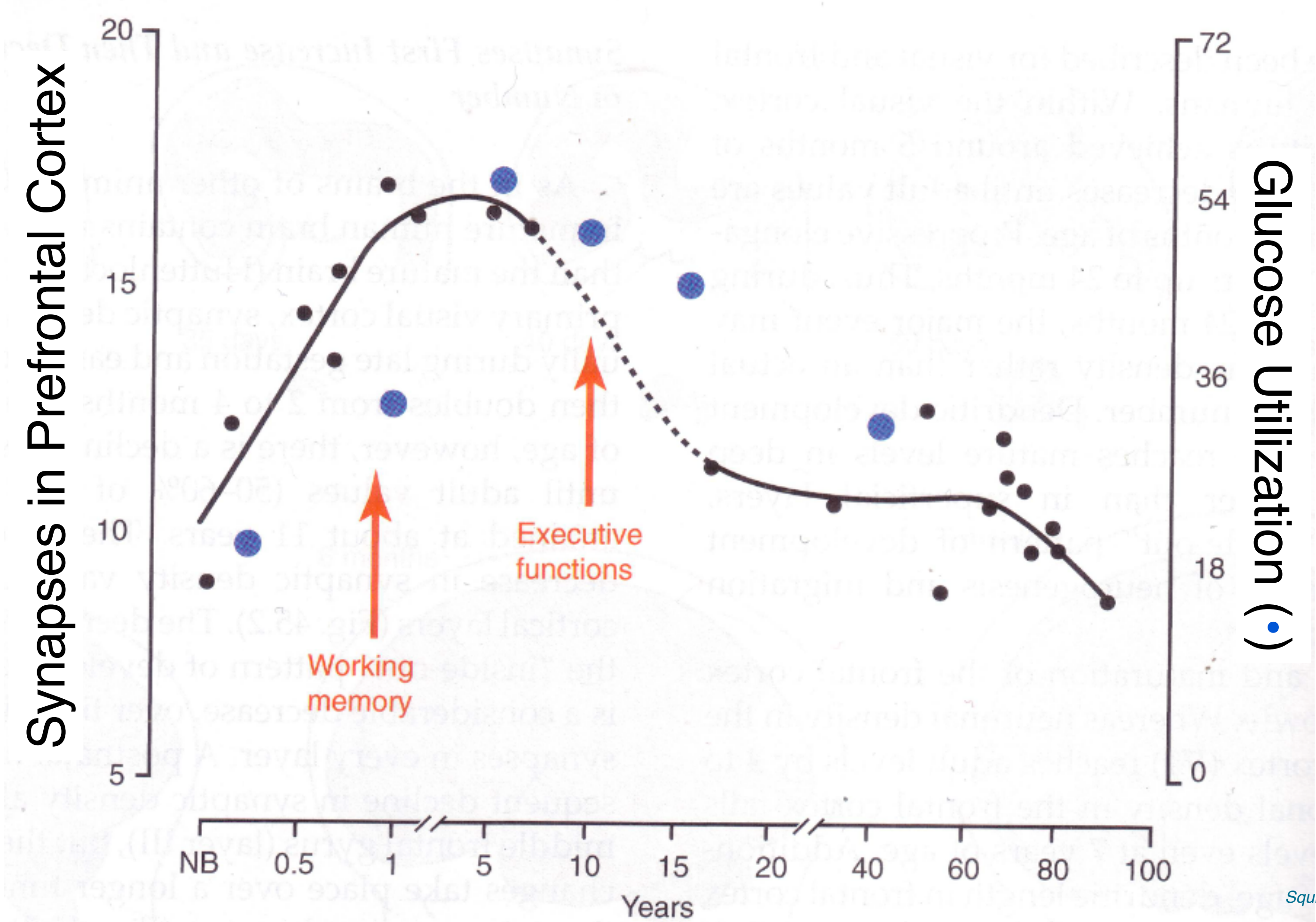
Decline in Brain Size with age



Brain size as a function of age. The human brain reaches its maximum size (measured by weight in this case) in early adult life and decreases progressively thereafter. This decrease presumably represents the gradual loss of neural circuitry in the aging brain, which presumably underlies the progressively diminished memory function in older individuals.

http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=neurosci&part=A2220

Decline in Number of Synapses



Squire 45.3

animation of neurons signaling
check volume


HHMI

Glial Cells

glia = glue. Support cells for neurons.
Provide electrical insulation, nutrition, and growth factors to neurons.

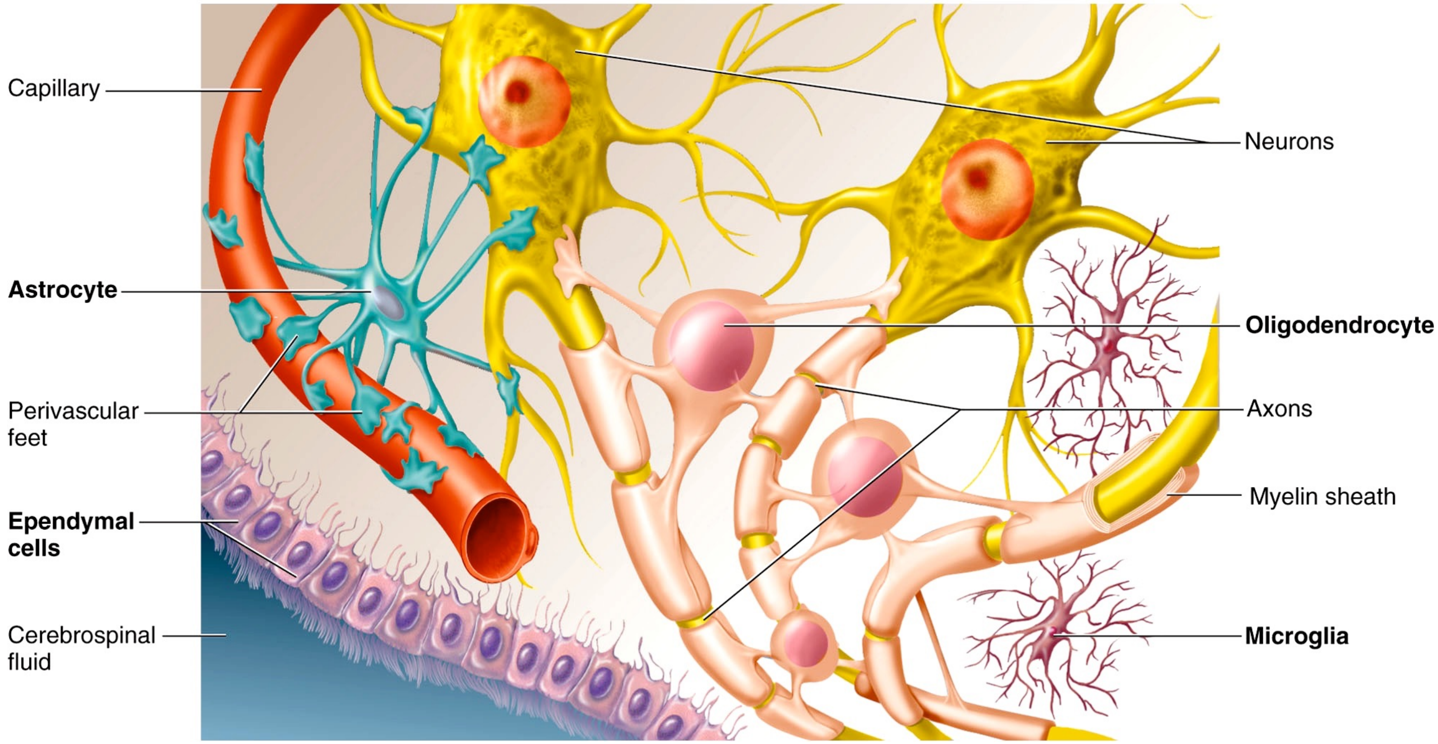
Schwann cells insulate peripheral axons.
Oligodendrocytes *(many branches)* insulate brain & spinal neurons.

Schwann cells & oligodendrocytes contain **myelin**, a fatty insulating compound = **white matter** of brain.

Schwann cells form sheath around axons of peripheral nerves. Transected peripheral nerves can regrow along nerve sheath to re-innervate target tissue. (Central nerves can **not** regenerate).

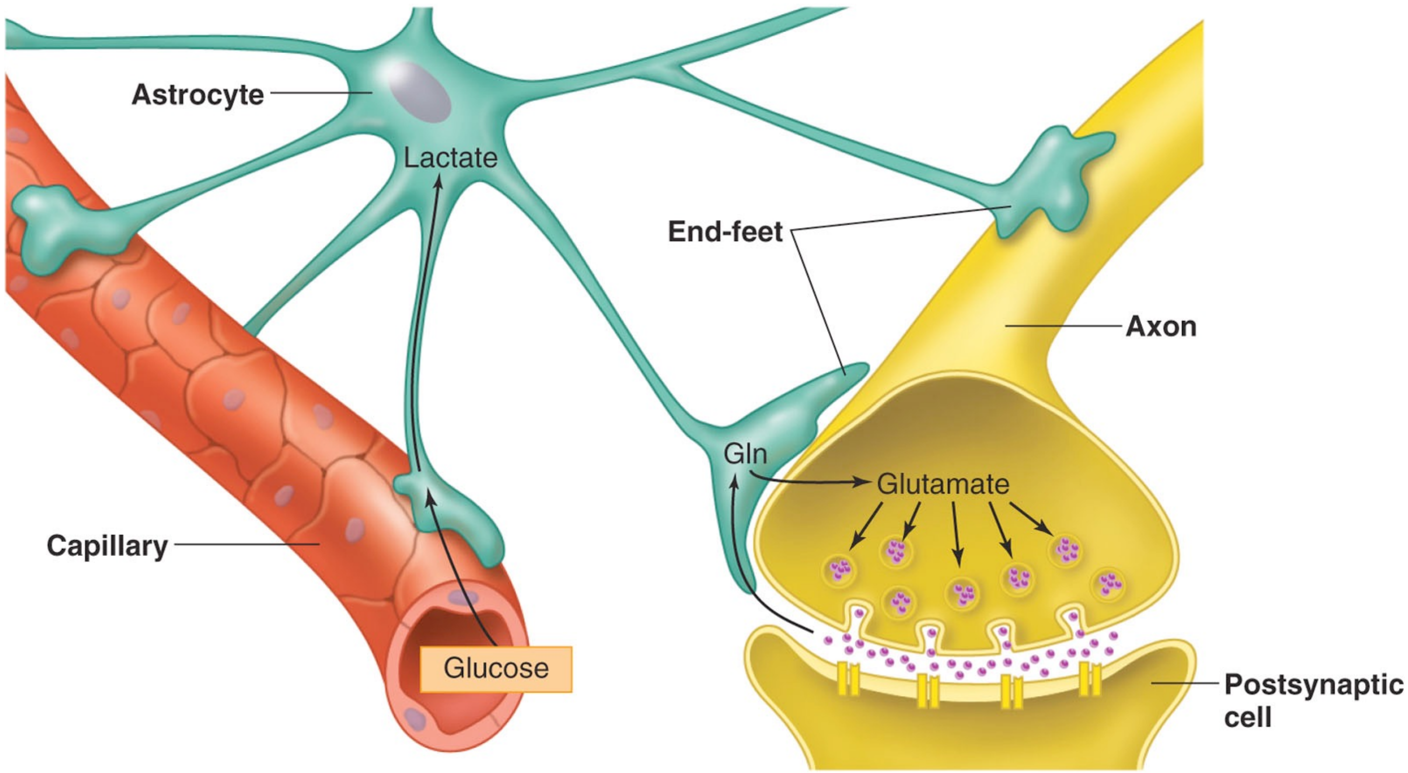
Schwann cells & Oligodendrocytes degenerate in multiple sclerosis (MS), leading to poor conduction of electrical signals along the axons

Astrocytes *(star-shaped)*
Provide nutrition to brain & spinal neurons.
Take up glucose from blood, convert to lactate, released for neurons.
Remove excess K+ and neurotransmitters from intracellular space.



Fox Figure 7.5

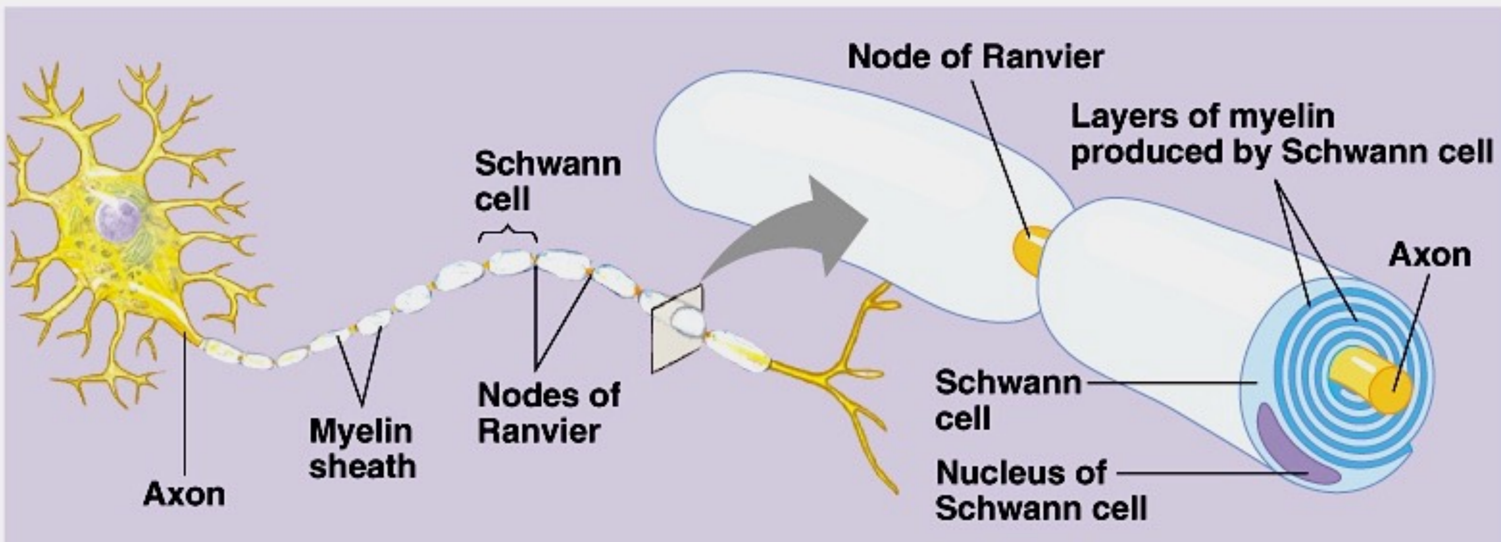
Astrocytes in the CNS convert glucose to lactate and release lactate for neurons to use.
Also remove excess K+, neurotransmitters (released by neurons) from intracellular fluid



Fox Figure 7.10

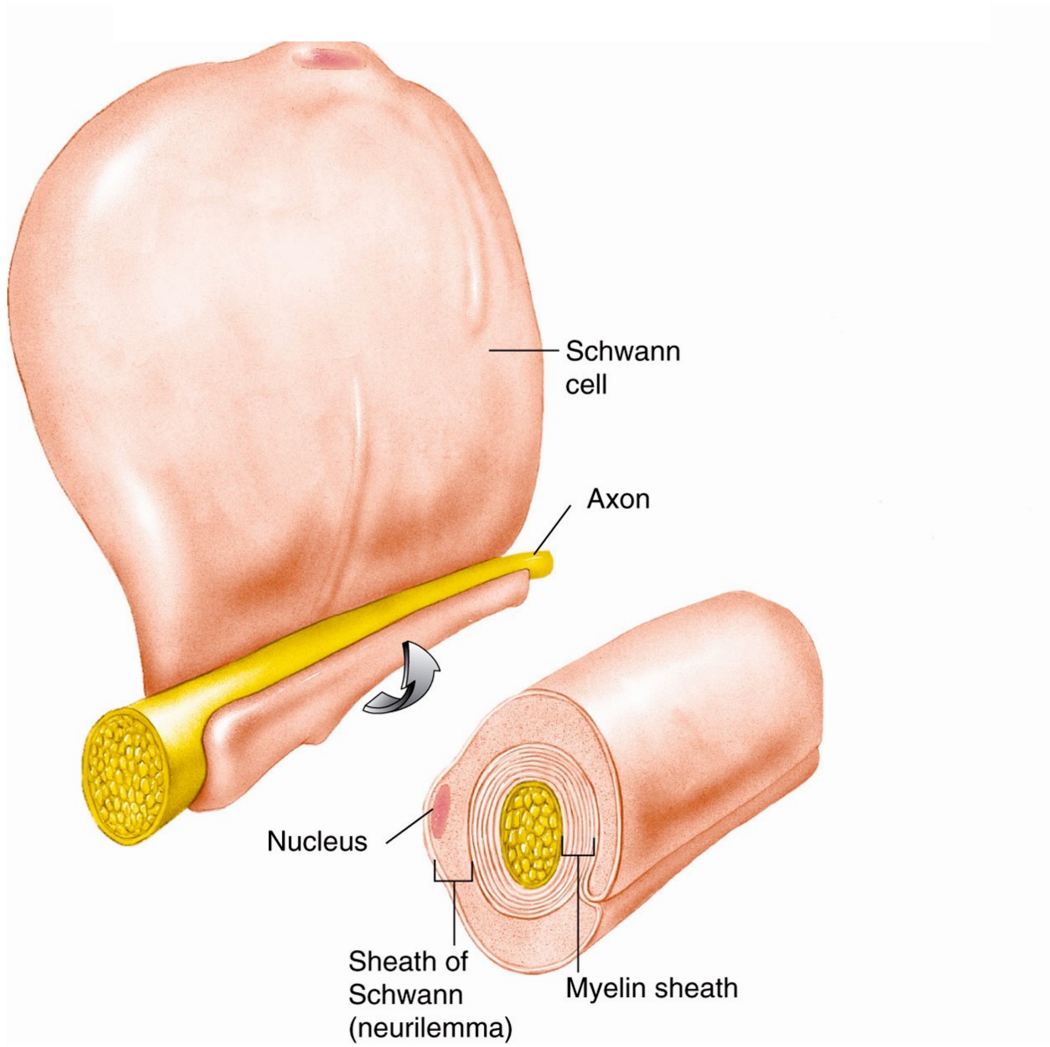
Schwann cells (and glial cells in brain) act as support and insulation for axons

Myelin is essential layers of fat wrapped around axon

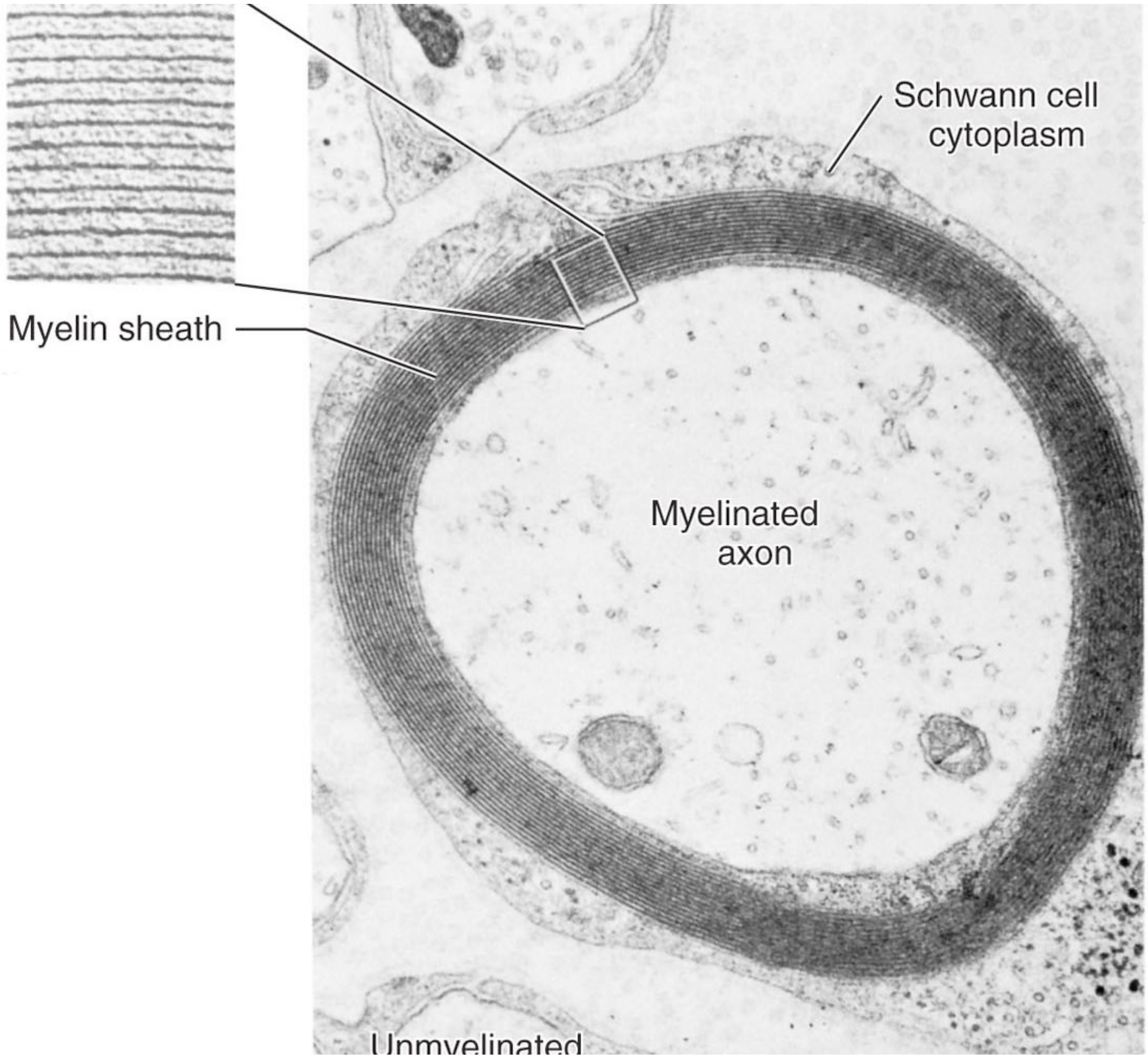


These cells die in MS, leading to “short-circuits” of axons: nerve’s transmission does not make it down the axon

Schwann Cells provide insulation for axons in the periphery

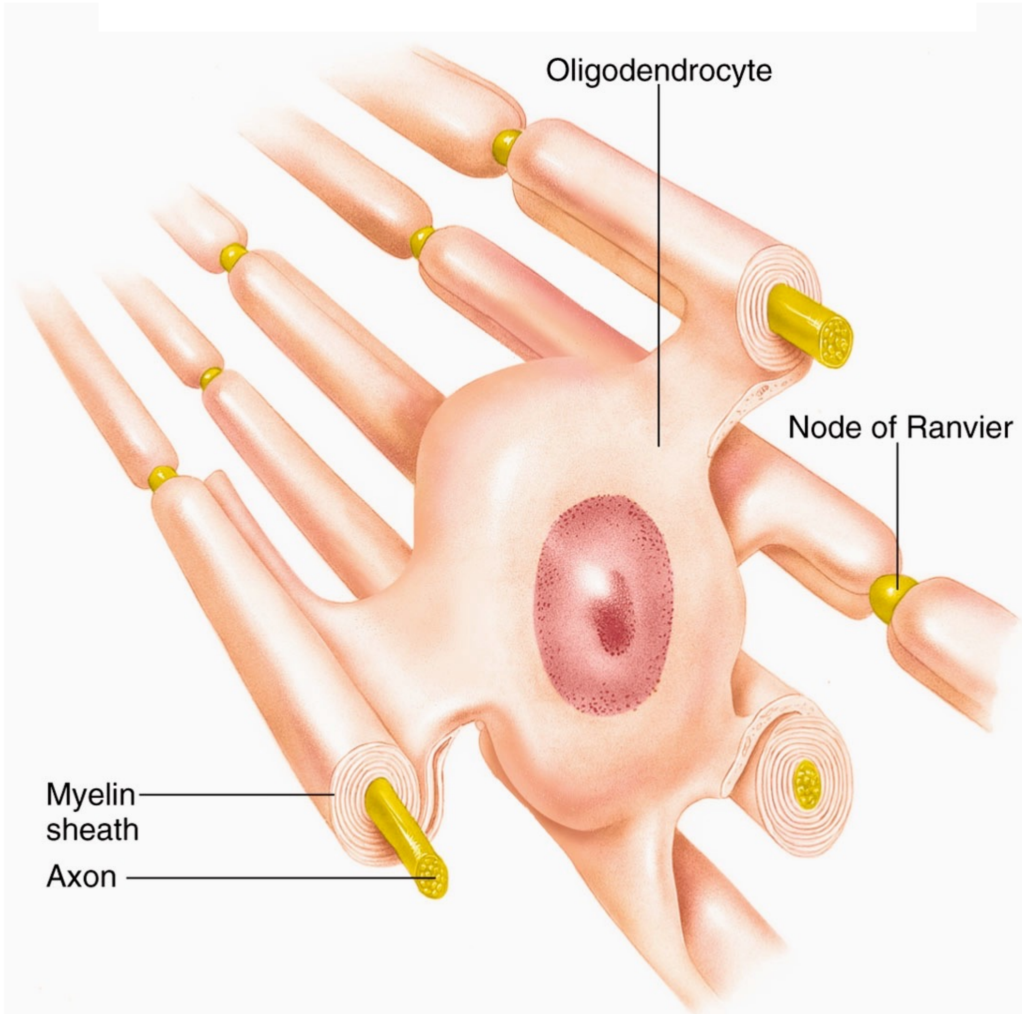


Fox Figure 7.6



Fox Figure 7.7

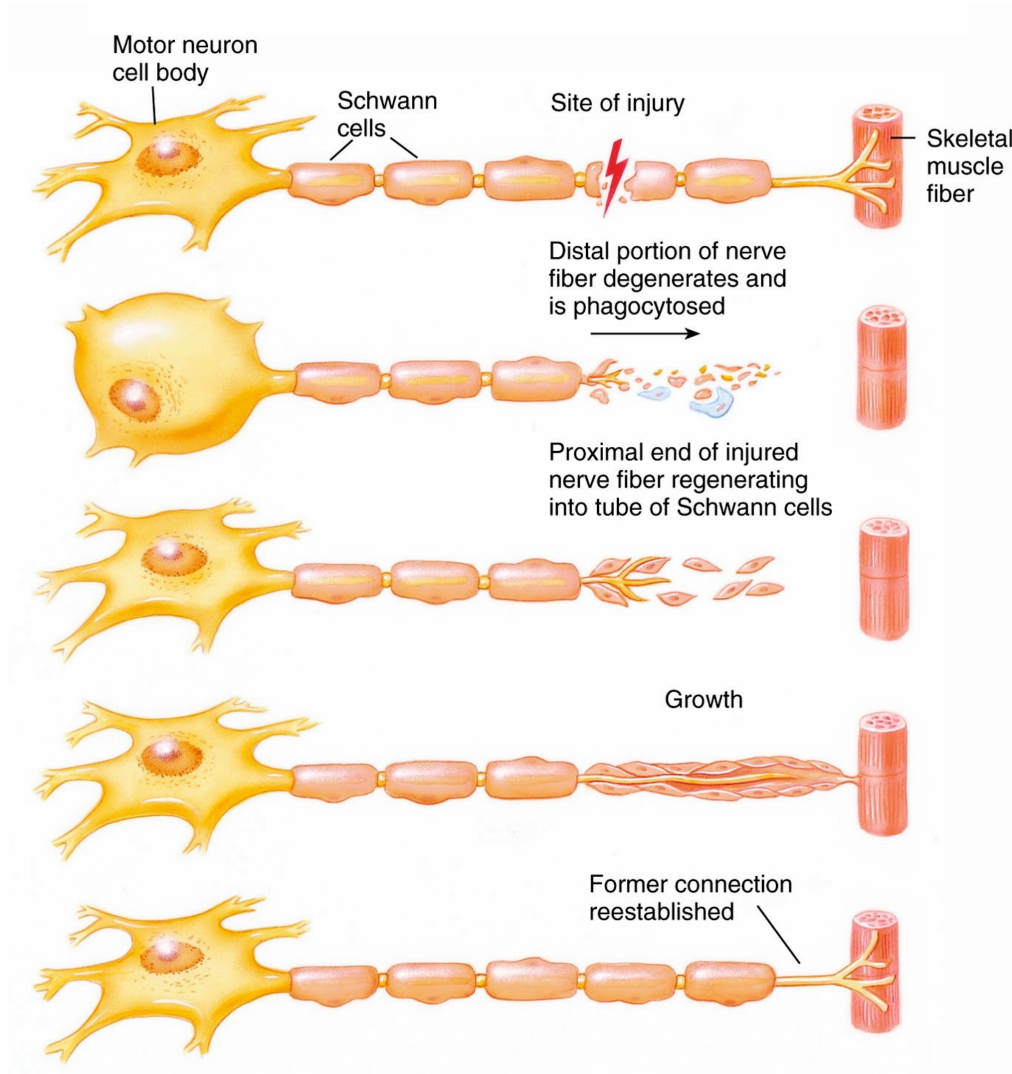
Oligodendrocytes provide insulation for axons in the CNS (brain and spinal cord)



Fox Figure 7.8

Peripheral Neurons can regenerate cut axons and grow back to target tissue, following sheath of glial cells.

If severed, Central Neurons don't grow back; glial cells in brain prevent regrowth (to prevent rewiring.)



Fox Figure 7.9

BRAIN.

PART III., 1908.

Original Articles and Clinical Cases.

A HUMAN EXPERIMENT IN NERVE DIVISION.

BY W. H. R. RIVERS, M.D., F.R.S.,
Fellow of St. John's College, Cambridge;

AND

HENRY HEAD, M.D., F.R.S.,
Physician to the London Hospital.

Several days after nerve transection

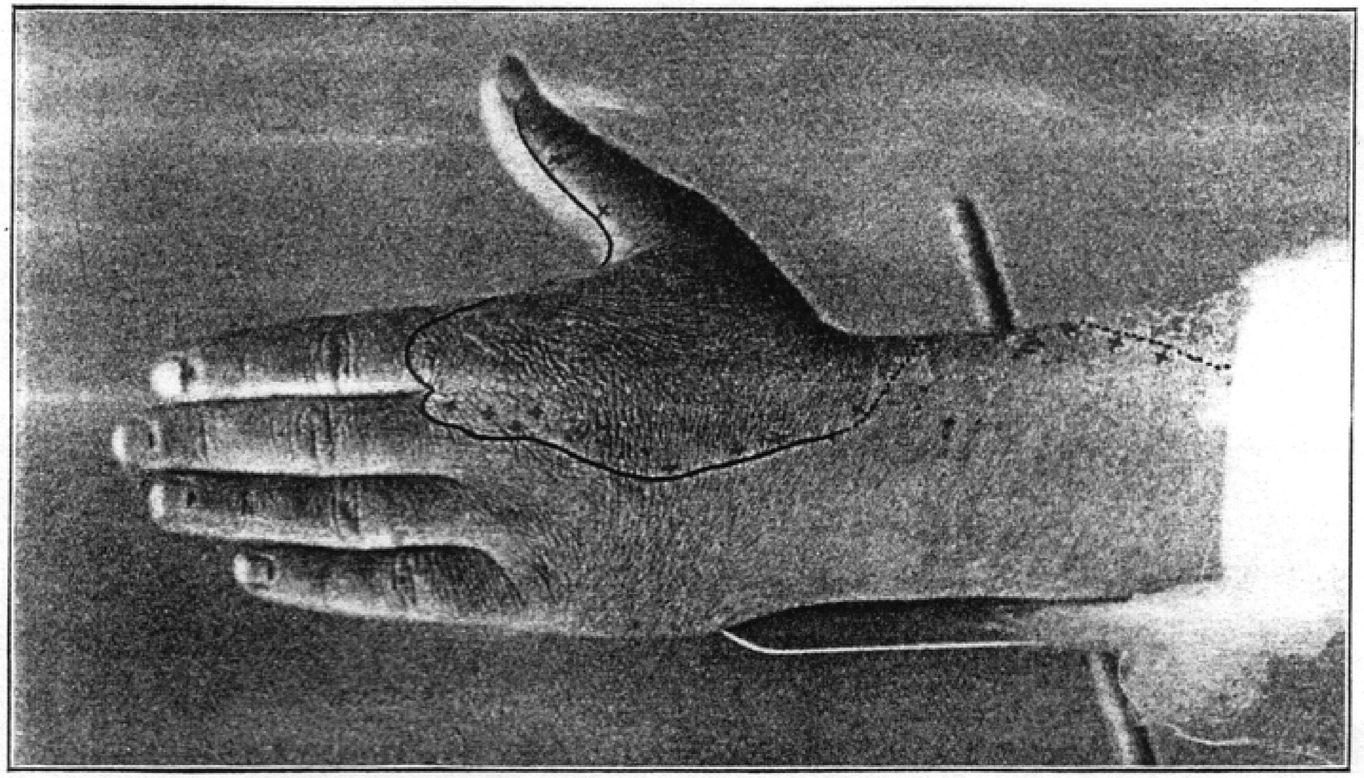


FIG. 1.

To show the extent of the loss of sensation produced by the operation.

The anæsthesia to cotton wool and to von Frey's hairs is bounded by the black line. The analgesia to prick and other cutaneous painful stimuli lay within the red crosses.

The darkness of the affected area is due to its deep red colour compared with the rest of the hand.

Several days after nerve transection (lateral view)

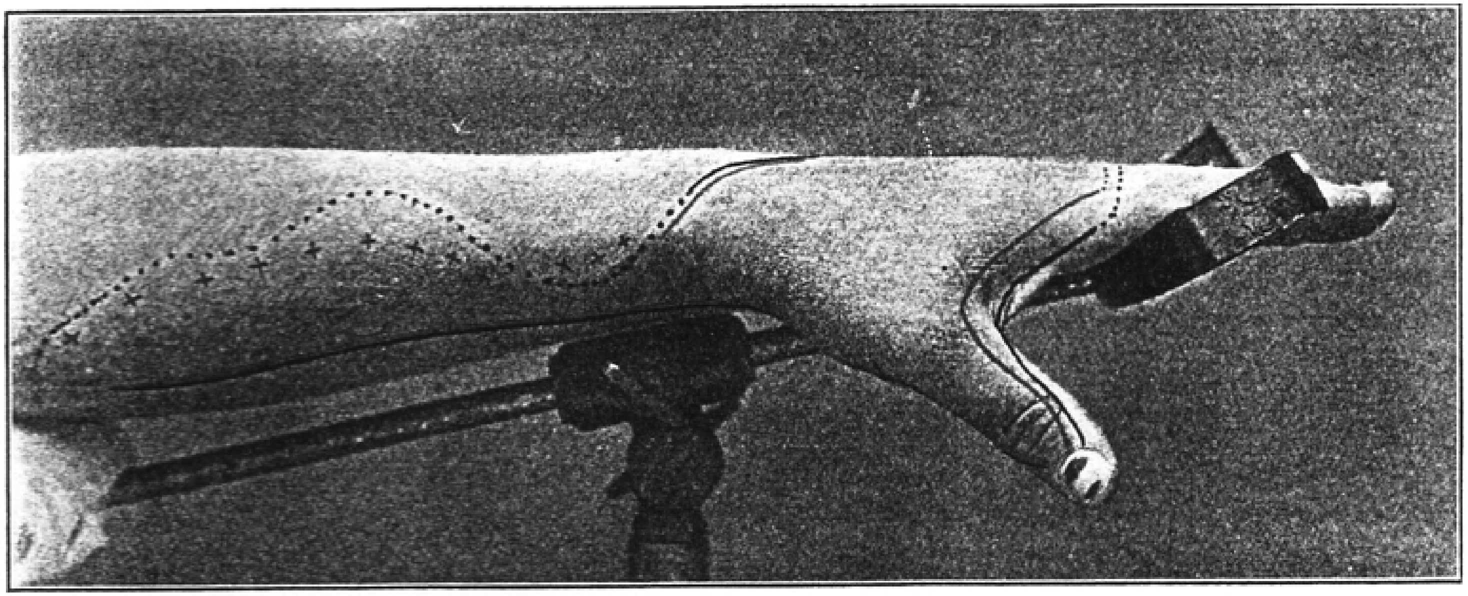


FIG. 3.

567 days after nerve transection

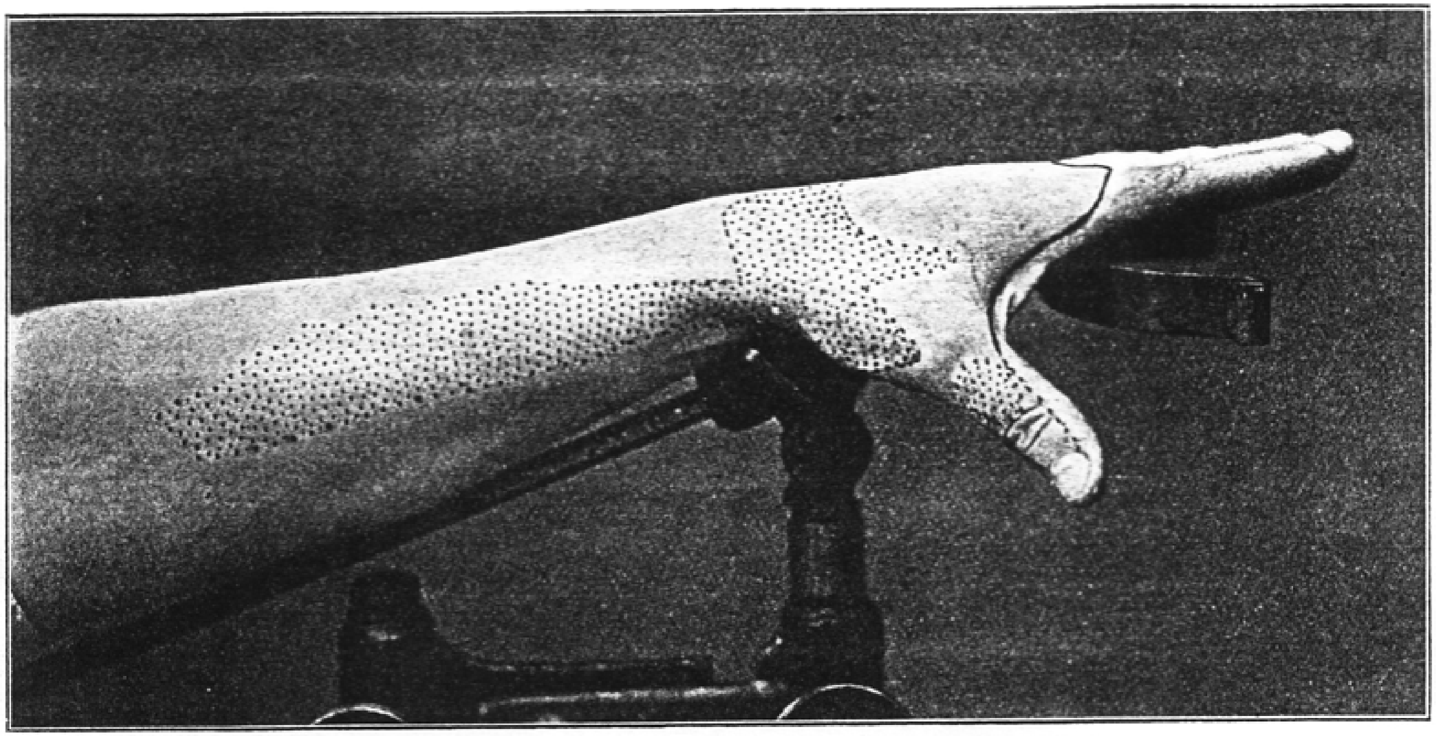


FIG. 13.

November 12, 1904 (567 days after the operation).

To show the manner in which sensibility returned to cutaneous tactile stimuli. The dotted area corresponds to the parts sensitive after shaving to cotton wool and to von Frey's tactile hairs (No. 5). These parts were also sensitive to temperatures of about 36° C.

5 years post-op:

still a patch w/o cutaneous sensitivity.

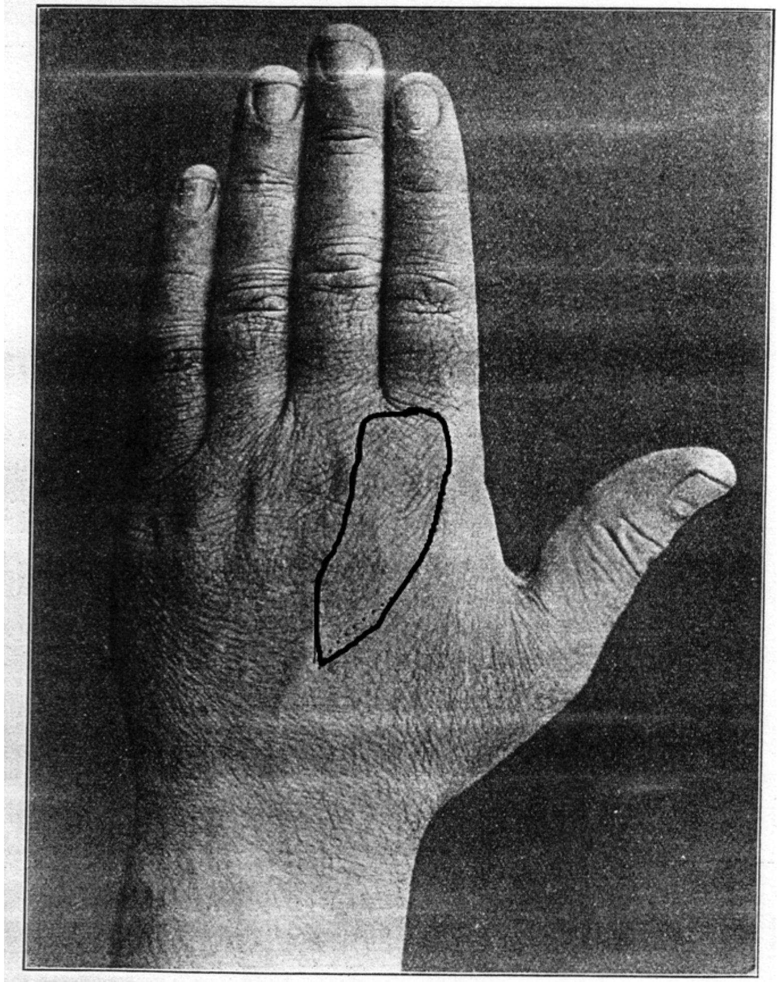


FIG. 14.
To show the extent of the affected area, which is still (1908) supplied with deep and protopathic sensibility only. Its radial border merges gradually into parts that have recovered more completely.

Order of recovery:
deep sensation, temperaure & pain, then fine discrimination.

Unlike Peripheral Nerves, spinal cord & brain neurons will NOT regenerate

Transected Peripheral Nerve Fibers can regenerate along nerve sheath and Schwann cells

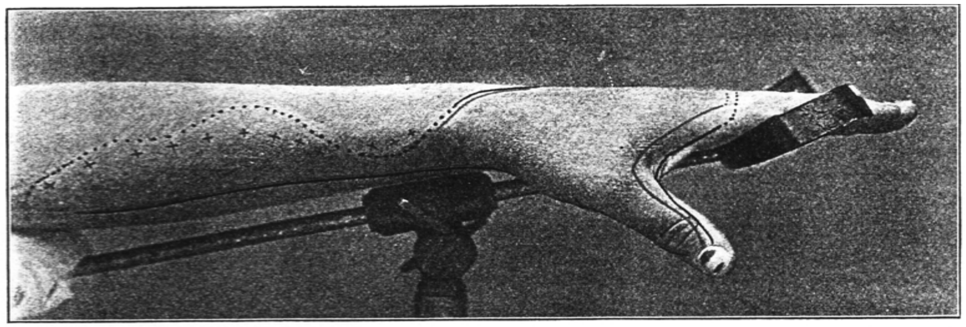
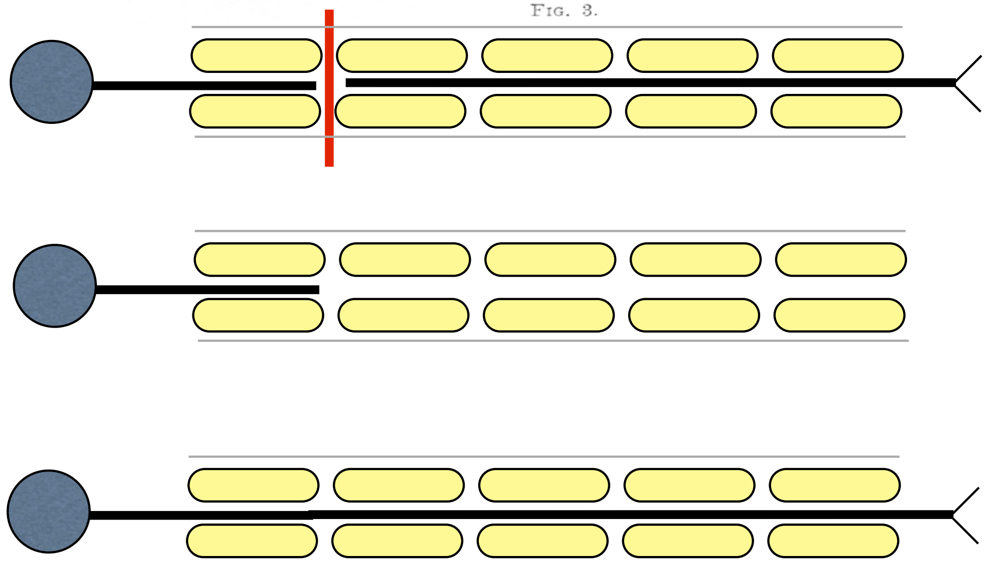
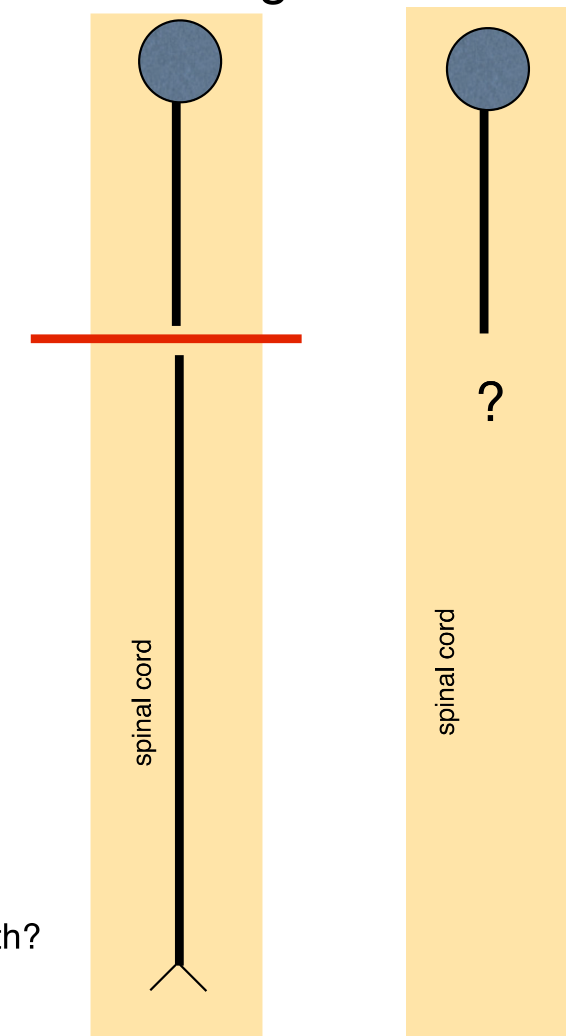


FIG. 3.

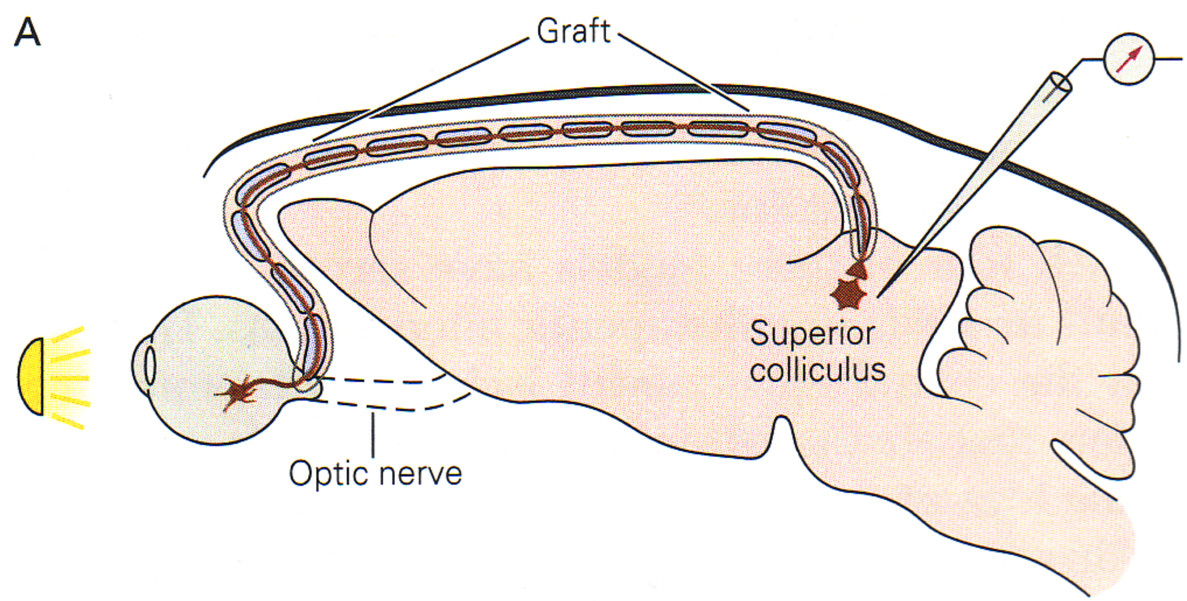


Transected Central Nerve Fibers do NOT regenerate through brain or spinal cord



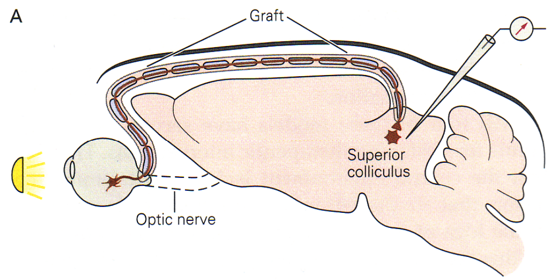
is this because central neurons can't regenerate?
or because brain/spinal cord tissue prevents regrowth?

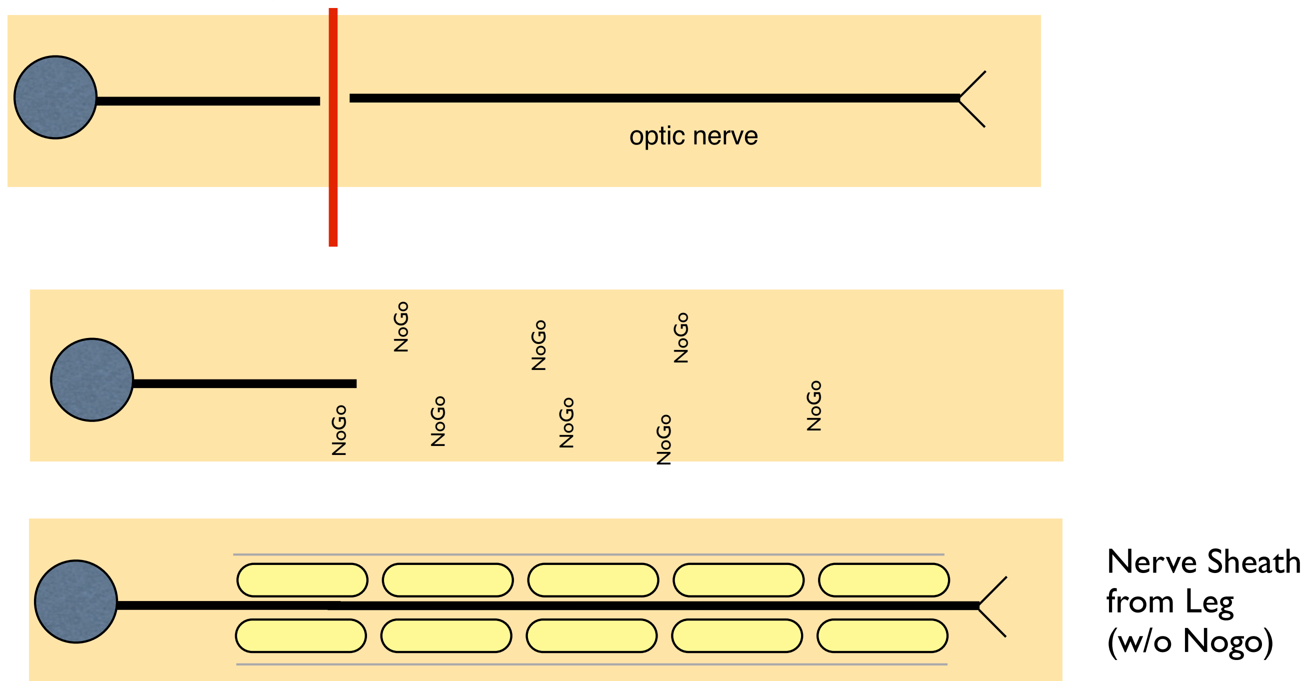
Peripheral Nerve Graft provides path for central axon regeneration



Thus, inhibition is environmental (property of brain tissue), not innate to neurons of central nervous system.

Central Glial cells secrete factors that block regrowth of axons: NoGo





Central Glial cells secrete factors that block regrowth of axons: NoGo